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THESIS

CORRELATION ANALYSIS: ARMY ACQUISITION PROGRAM CYCLE TIME AND COST VARIATION

by

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September 1999

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13. ABSTRACT *(maximum 200 words)*

A changing threat environment, decreasing defense budget, and need for modernization are forcing the Acquisition Process to reform policies and procedures. The Acquisition Process must develop initiatives to reduce both program cycle time and program cost to meet the challenges presented by this new acquisition environment. The objectives of this thesis are to explore the overall cycle time and cost growth trends in Army Acquisition Programs, and determine how program schedule growth affects program cost. This analysis is relevant in facilitating development of acquisition reform initiatives targeted at reducing program schedule and cost. This study concludes that Army programs experience average cycle time growth of 19.6 months and average cost growth of 49.9%. A significant research finding is that Army programs demonstrate a relationship between schedule growth and cost growth. This research also reveals that program cost growth, identified in the SARs as being induced by schedule growth, is only 14.3% of cost growth adjusted for quantity change. This thesis suggests that schedule growth has a larger effect on cost growth than indicated in the SARs. This research intends to function as an overview of Army Acquisition Program schedule and cost growth, and the relationship between these two important program elements.

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CORRELATION ANALYSIS: ARMY ACQUISITION PROGRAM CYCLE TIME AND COST VARIATION

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ABSTRACT

A changing threat environment, decreasing defense budget, and need for modernization are forcing the Acquisition Process to reform policies and procedures. The Acquisition Process must develop initiatives to reduce both program cycle time and program cost to meet the challenges presented by this new acquisition environment. The objectives of this thesis are to explore the overall cycle time and cost growth trends in Army Acquisition Programs, and determine how program schedule growth affects program cost. This analysis is relevant in facilitating development of acquisition reform initiatives targeted at reducing program schedule and cost. This study concludes that Army programs experience average cycle time growth of 19.6 months and average cost growth of 49.9%. A significant research finding is that Army programs demonstrate a relationship between schedule growth and cost growth. This research also reveals that program cost growth, identified in the SARs as being induced by schedule growth, is only 14.3% of cost growth adjusted for quantity change. This thesis suggests that schedule growth has a much larger effect on cost growth than indicated in the SARs. This research intends to function as an overview of Army Acquisition Program schedule and cost growth, and the relationship between these two important program elements. This thesis generated numerous results that should be explored with further detailed analysis.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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This research entailed a great deal of numerical extraction, manipulation, and calculations. Utmost care is taken to ensure this research document is error free. However, any errors discovered in this research paper are unintentional and the sole responsibility of the author.

I. INTRODUCTION

> My No. 1 priority is to get systems fielded that will be useful to our combat forces and to do that as quickly and with as low a cost as we possibly can. The military advantage goes to the nation who has the best cycle time to capture technologies that are commercially available, incorporate them in weapon systems and get them fielded first (Kaminski, 1997, p.2).

A. PURPOSE

The purpose of this research is to determine Army Acquisition Programs' cycle time and cost variation, and determine if a statistical relationship exists between schedule and cost variation. Cycle time and cost data are obtained for the Army Acquisition Programs from the DoD Cycle Time Analysis Tool (CTAT) and from Selected Acquisition Reports (SAR), respectively. Two groups of Army Programs are analyzed: twenty-one programs that incorporate the entire acquisition cycle from Milestone I (MS I) to Initial Operational Capability (IOC) and fourteen modification programs that incorporate a modified cycle time from MS II to IOC. This research will provide acquisition workforce personnel with a better understanding of the relationship between a program's schedule and cost. It will also help measure the effects of documented program changes in terms of estimated cycle time and cost variation.

This research will facilitate the development of future acquisition cycle time and cost reform initiatives. If a correlation between a program's schedule and cost exists, then policy makers can target reform initiatives to reduce cycle time. A reduced cycle time will also provide the added benefit of a reduced program cost. If no correlation exists between schedule and cost, policy makers must then develop reform initiatives that target cycle time and cost reduction separately.

B. BACKGROUND

In July 1999, the House Appropriation Committee voted to stop production of the F-22 Raptor, and cut $1.8 Billion of the $3 Billion requested for this program in FY 2000 funding (Associated Press, 1999). This action was initiated because of cost growth problems in the F-22 program. Development costs are projected to increase by $1 Billion, and the overall F-22 program cost is projected to increase by $13 Billion. The per unit cost has doubled to $184 Million per airplane (Schneider, 1999). The RAH-66 Comanche is experiencing similar problems. This aircraft's unit cost has doubled since 1985 and the program's schedule has slipped by 81 months (GAO Report, 1992). These two programs are only two examples of a larger defense acquisition problem.

Cost growth and schedule delays are two of the oldest, most visible, and common problems associated with the acquisition of military weapon systems. Programs, across the services, have commonly experienced cost growths of 20 to 40% and many programs experience cost growth much higher than 40%. Also almost every DoD program experiences schedule slippage, with some program schedules slipping by over 4 years. (GAO Report, 1992)

The Defense System Affordability Council (DSAC) is recommending that the acquisition program cycle time be reduced by as much as 50%. Department of Defense (DoD) personnel believe that this cycle time reduction will reduce program cost and improve effectiveness. (White Paper, 1997) DoD personnel believe that cost and schedule are interdependent. "A schedule delay, assuming program scope is not reduced, will likely drive cost up (GAO Report, 1992, p.7)." The opposite should also hold true, schedule reduction should decrease program cost. However, before implementing

policies aimed at reducing cycle time; further research needs to be completed to understand actual cycle time and cost variations within military services, and the interrelationship between these two essential aspects of an acquisition program.

At this time, many conditions are converging which are increasing the importance of program cycle time and cost variation research. The three main conditions are the change in threat environment, decreasing defense budget, and the need for modernization. Understanding acquisition program cycle time and cost variation is necessary to solve some of the challenges presented by these convergent conditions.

1. Change in Threat Environment

The current DoD Acquisition Process is structured to solve technical problems based on a stable, known threat. However, the United States no longer faces a single threat like the former Soviet Union. Macgregor (1997) states that a revolution in military affairs (RMA) as occurred in the post-Cold War era. The future battlefield has become fluid and complex, focusing on peacekeeping operations like Bosnia, Haiti, Somalia, and Kosovo. Today's United States military forces must be able to react to various threats. Sanders (1997) states, "in statistical terms, the mean value of our single greatest threat is considerably reduced, however, the variance of the collective threat has increased" (p.1).

The average cycle time for DoD Acquisition Programs, program initiation to Initial Operational Capability, is estimated to be 9 to 11 years. The commercial sector is developing technological innovations at a much faster pace. The commercial computer sector's technology cycle is between 12 to 18 months. (White Paper, 1997)

2. DoD Budget Decrease

During this same period, the defense budget has decreased from a high of $418.4 billion in 1985 to the current level of $257.3 billion, a 38.5% decrease. Within the defense budget, the Procurement account has decreased from $136.4 billion or 32.6% of the overall defense budget to $48.7 billion or 18.9% of the defense budget. The Research, Development, Test, and Evaluation (RDT&E) account has decreased from $45.1 billion or 10.8% of the overall defense budget to $36.1 billion or 14.0% of the defense budget. (Defense Budget Materials, 1999)

3. Need for Modernization

To further compound the current situation, the equipment and systems currently used by DoD soldiers are nearing the end of their expected lifetime. These systems will soon need to be replaced with upgraded systems incorporating the newest technology. The military must be able to develop, produce, and field these new systems within the constraints of the reduced defense budget and at an accelerated cycle time required to adapt to an ever-changing threat environment. Programs that take decades to develop increase cost and are less effective when eventually fielded to the operational user. The operational user deserves a system that incorporates the latest technology, which can be fielded quickly to meet threat requirements.

C. RESEARCH QUESTIONS

1. Primary Research Question

How do variations in Army Acquisition Program cycle time affect program cost?

2. Secondary Research Questions

a. What is the traditional DoD Acquisition Process?

b. Why is program acquisition cycle time and cost variation important?

c. What are Selected Acquisition Reports and why are they important?

d. What are program cycle time and cost and how are they determined within the Acquisition Process?

e. What are the cycle time and cost variation in Army Acquisition Programs?

D. SCOPE OF THESIS

This research examines SAR cycle time and cost data in order to analyze the cycle time and cost variation relationship of selected Army Acquisition Programs from 1969 to 1998. The Army Acquisition Programs are divided into two major groups: twenty-one full acquisition cycle programs and fourteen modification programs. Each of these groups are further divided into five commodities:

- Tactical Missiles
- Command, Control, Communication, and Intelligence (C3I)
- Helicopters
- Precision Guided Munitions (PGM)
- Vehicles

This research determines schedule and cost variation for the selected Army Acquisition Programs as reported by the program SARs and the CTAT database. This research also explores whether a relationship exists between program cycle time and cost variation. Understanding the relationship between cycle time and cost will provide insight for future acquisition cycle time and cost reform initiatives. This research will also add to the effort to increase the accuracy of cost estimation due to schedule changes.

E. METHODOLOGY

The first objective of this research is to familiarize the reader with the DoD Acquisition Process and SAR information. Next, the importance of cycle time and cost variation in the acquisition process is explored. Then, information is presented on program cycle time and cost variation. A literature review of the following sources is conducted:

- Published academic research papers, magazine articles, and books
- DoD publications and regulations (5000 & 7000 series)
- Internet websites
- Interviews with experts on the topic of cost growth

Once a framework is provided for understanding the importance of this analysis, Army Acquisition Program SAR data is evaluated and organized in tabular form as shown in Appendices A, B, D, and E. SAR data from the 35 Army Acquisition Programs is initially analyzed using descriptive statistics to determine the cycle time and cost variation. Next, regression analysis is conducted to determine if a relationship exists between cycle time variation and cost variation. This data is also presented in tabular and graphical formats.

F. ORGANIZATION

Chapter II (Background) provides an overview of the current DoD Acquisition Process to include an understanding of SARs. This chapter also includes a section that explains why cycle time and cost variation analysis is important to DoD system acquisition management.

Chapter III (Cycle Time and Cost Variation) defines program cycle time and cost variation, and discusses the methodologies used to analyze the cycle time and cost data.

This chapter concludes with a discussion of the advantages and the difficulties associated with using SAR data to analyze cycle time and cost variation.

Chapter IV (Cycle Time and Cost Variation Analysis) provides an analysis of schedule and cost variation. Descriptive statistics are used to compare and contrast cycle time and cost variation between and within the two major Army Acquisition Program groups: full acquisition cycle programs and modification programs. This analysis identifies the phases in the acquisition process where the greatest variation occurs, which program commodity experiences the greatest variations, and determines the average program length for the selected Army acquisition programs.

Chapter V (Cycle Time and Cost Variation Correlation) provides a regression analysis of the relationship between program cycle time, schedule induced cost variation, and overall program cost variation. The analysis of this data will assist acquisition workforce personnel to more accurately estimate cost variation due to schedule changes.

Chapter VI (Summary, Conclusions, and Recommendation) summarizes the finding of the analysis, presents conclusions based on the research results, and identifies recommended topics for further research efforts.

G. BENEFITS OF THE STUDY

This research will benefit all acquisition workforce personnel to include DoD policy makers, program management personnel, and operational users. This research helps identify which phases of the acquisition process and which program commodities have the greatest schedule and cost variation. This analysis also compares and contrasts variation between different Army programs (full acquisition cycle vs. modifications), between Army program commodities, and between phases of the acquisition process. The primary benefit of this

research is to determine if a relationship exists between cycle time variation, schedule induced cost variation, and overall program cost variation.

II. BACKGROUND

A. INTRODUCTION

This chapter provides an overview of the current DoD Acquisition Process. This overview includes an understanding of the requirements generation process, acquisition milestones and phases, and an explanation of acquisition categories. This chapter also includes a section that discusses SARs, and explains why cycle time and cost variation analysis is important to DoD system acquisition management.

B. OVERVIEW OF DOD ACQUISITION PROCESS

This section provides information on three systems of the DoD Acquisition Process: the requirements generation process; acquisition management milestones / phases; and the Planning, Programming, and Budgeting System (PPBS). These three systems must be integrated to ensure decision-makers have the necessary information to make accurate decisions. This section also discusses the program acquisition categories. An understanding of each of these acquisition elements is important in order to understand the data analysis presented in Chapters IV and V. The information in these later chapters is presented in a manner that assumes the reader has a basic understanding of the ideas and terms discussed in this section.

1. Requirements Generation Process

The Defense Acquisition Process actually begins with the development of the National Security Strategy (NSS). The NSS is formulated by the National Command Authority (NCA), the President and Secretary of Defense, and the National Security Council (NSC). This strategy must account for the use of military force from humanitarian

assistance to peacekeeping operations, and from conventional warfare to nuclear operations. (Przemieniecki, 1993)

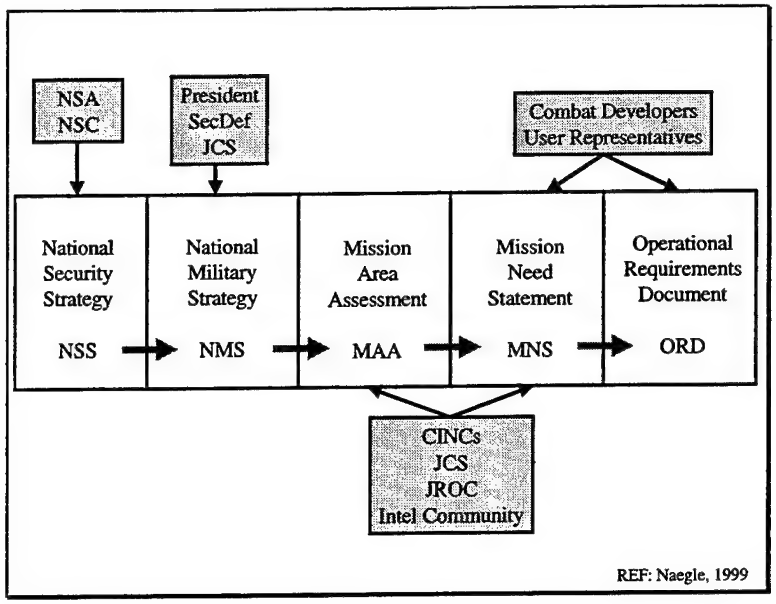

Figure 1: DoD Requirement Generation Process

The NSS leads to the development of the National Military Strategy (NMS). The NMS facilitates regional mission development by the various commands. Mission Area Assessment (MAA) is conducted to determine if the capabilities exist to accomplish the necessary missions identified by the NMS. The MAA provides analysis that ascertains the availability, suitability, and effectiveness of current systems. Mission deficiencies are identified and provide the basis for development of the Mission Need Statement (MNS). "The MNS is the major step in the Defense Requirements Process before the Acquisition Process for new systems begins" (Przemieniecki, 1993, p.10).

2. Acquisition Management Milestones / Phases

The DoD Acquisition Process consists of four phases and four decision points called milestones as shown in the following diagram (Mathews, 1998).

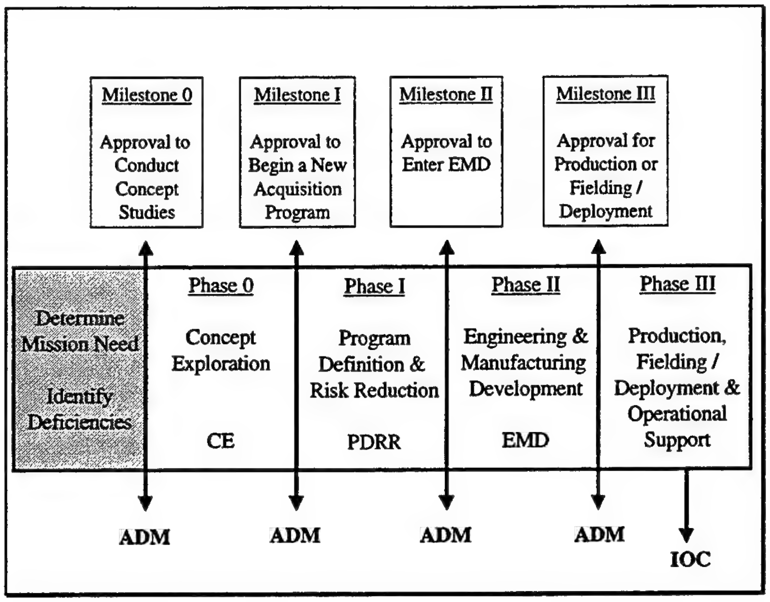

Figure 2: DoD Acquisition Process

a. Milestone 0 / Phase 0

Milestone 0 is the approval to conduct concept studies. Upon validation of a mission need for a new program, a MS 0 Defense Acquisition Board (DAB) is convened to identify possible non-material alternatives, material alternatives, and approve concept studies if required. At the conclusion of the MS 0 DAB, an Acquisition Decision Memorandum (ADM) is prepared. The MS 0 ADM identifies the minimum set of alternative concepts to be researched, identifies the lead organization for the research, establishes Phase 0 exit criteria, and identifies the funding amount and source for the research. (Mathews, 1998) MS 0 approval does not initiate a new program. This approval only provides authority to begin Phase 0 (DoD Directive 5000.2R).

Phase 0 of the acquisition process is called Concept Exploration (CE). During this phase, the lead agency finalizes the MNS that drives the alternative concept research. This phase consists of exploring the identified number of alternative concepts in terms of cost, schedule, and performance objectives. (Mathews, 1998) These objectives are

incorporated into an Acquisition Program Baseline (APB). Acquisition Strategies are developed for each promising concept, an initial Operational Requirements Document (ORD) is prepared, and Phase I exit criteria are defined (DoD Directive 5000.2R).

b. Milestone I / Phase I

Milestone I is the approval to begin a new acquisition program. The Milestone Decision Authority (MDA) must approve the acquisition strategy, the APB, and the Phase I exit criteria. The previous three concepts are incorporated into the MS I ADM. Also testing personnel on the DAB will review and approve the Test and Evaluation Master Plan (TEMP). Upon approval of MS I, a Program Management Office (PMO) is established to manage the new program. (DoD Directive 5000.2R)

Phase I of the acquisition process is called Program Definition and Risk Reduction (PDRR). During this acquisition phase, the newly initiated program is defined by the promising concepts in terms of design approaches and required technologies. The use of prototyping and early operational assessments are used to reduce program risk and evaluate critical technologies and processes (DoD Directive 5000.2R). The objective of PDRR is to understand the technology, manufacturing, and support risks of the program. The Program Manager (PM) must identify and evaluate possible tradeoffs between cost, schedule, and performance objectives in the APB (Mathews, 1998). As in Concept Exploration, exit criteria for Phase II must be established prior to MS II.

c. Milestone II / Phase II

Milestone II is the approval to enter Phase II. The objective of the Milestone II decision is to determine if the analysis conducted in PDRR supports a continuation of the program. During this milestone review, the MDA must approve the updated acquisition

strategy, the updated APB (development baseline), and the identified Phase II exit criteria. As with the two previous milestone decisions, an ADM provides written evidence of the MDA's approval.

Phase II of the acquisition process is called Engineering and Manufacturing Development (EMD). The best concept alternative is transformed into a cost-effective, stable design. Developmental Testing (DT) is conducted to ensure system capabilities satisfy performance requirements. Low Rate Initial Production (LRIP) occurs in order to produce a small number of systems. The LRIP systems validate the production process and are utilized in Operational Testing (OT) later in the phase. (DoD Directive 5000.2R)

d. Milestone III / Phase III

Milestone III is approval to enter acquisition Phase III. During this milestone review, the MDA will approve the updated acquisition strategy, the updated APB (production baseline), and the Phase III exit criteria as needed.

Phase III of the acquisition process is called Production, Fielding / Deployment, and Operational Support. The objective of this phase is to achieve production capability resulting in a system operational capability that meets mission suitability and effectiveness requirements (DoD Directive 5000.2R). During this phase, a system will reach Initial Operational Capability. IOC is the first capability to effectively employ a weapon system or piece of equipment. Effectively employ means the weapon system is operated by a trained and equipped military unit. An IOC date is usually established early in the program based on mission threat (Sammet & Green, 1990, p.436).

3. Planning, Programming, and Budgeting System (PPBS)

The third important aspect of the Defense Acquisition System is the PPBS process. The PPBS is a management process that develops the DoD portion of the Executive Budget that is submitted to Congress. The PPBS is a cyclic, calendar-driven process that the DoD personnel utilize to develop its yearly budget. (Schmoll, 1996)

Besides preparing the annual budget, the PPBS is also used to adjust the Future Years Defense Program (FYDP), which includes DoD requirements for the five years after the next budget year. The PPBS is broken up into three separate sections; Planning, Programming, and Budgeting. The planning phase begins in the fall and ends with the development of the Defense Planning Guidance (DPG). (Schmoll, 1996)

The programming phase is the connection between the planning phase and the detailed price estimate of each program required in the budget phase. Service and Defense agencies use the DPG to develop their own Program Objective Memoranda (POM). The POM is a request by these agencies to receive the required resources to accomplish their missions. (Schmoll, 1996)

The budgeting phase is controlled by the Assistant Secretary of Defense (Comptroller) (ASD(C)). In this phase, the Service and Defense agency POMs are reviewed and Budget Estimate Submissions (BES) are prepared. The BESs are sent by the Service and Defense agencies to the OSD and then to the Office of Management and Budget (OMB). The BESs are included in the Executive Budget request that is submitted to Congress. (Schmoll, 1996)

4. Acquisition Program Categories

After approval to initiate a new acquisition program, that program is assigned as one of the following Acquisition Categories (ACATs):

a. ACAT I Programs

Programs assigned to this category are also called Major Defense Acquisition Programs (MDAPs). A program must meet at least one of the following prerequisites to be designated as an ACAT I program. The estimated RDT&E cost must exceed $355 Million (FY 96 dollars) or the estimated procurement cost must exceed $2.135 Billion (FY 96 dollars). If a program does not meet either of these criteria, it can still be designated an ACAT I program by the Under Secretary of Defense (Acquisition and Technology) (USD(A&T)) (DoD Directive 5000.2R). The ACAT I programs are further divided into ACAT ID and ACAT IC programs. The MDA for ACAT ID programs is the USD(A&T), and the MDA for ACAT IC programs is the DoD Component Head.

b. ACAT IA Programs

Programs assigned to this category are also called Major Automated Information Systems (MAIS). A Command, Control, Communication, and Intelligence (C3I) program must meet at least one of the following prerequisites to be designated as an ACAT IA program. The estimated program single-year cost must exceed $30 Million (FY 96 dollars). The estimated total program costs must exceed $120 Million (FY 96 dollars) or the estimated program total Life-Cycle Cost (LCC) must exceed $360 Million (FY 96 dollars). If a program does not meet any of these criteria, it can still be designated an ACAT IA program by the Assistant Secretary of Defense (C3I) (ASD (C3I)) (DoD Directive 5000.2R). As with the ACAT I programs, the ACAT IA programs are also divided into two

categories, ACAT IAM and ACAT IAC. The MDA for the ACAT IAM programs is the Office of the Secretary of Defense (OSD) Chief Information Officer (CIO). The MDA for the ACAT IAC programs is the DoD Component CIO.

c. *ACAT II and ACAT III Programs*

Programs can also be designated as ACAT II or ACAT III categories. A program is designated ACAT II if the program is a major system, but it does not meet the requirements for designation as an ACAT I program. A major system is defined as a "combination of elements that shall function together to produce the capabilities required to fulfill a mission need to include hardware, equipment, software, or any combination thereof, but excluding construction or other improvements of real property (DoD Directive 5000.2R, 1.3.3)." An ACAT II program also requires a total cost of $135 Million RDT&E funds (FY 96 dollars) or more than $640 Million Procurement funds (FY 96 dollars).

ACAT III programs are any programs that do not meet the requirements for designation as any of the previously described categories. The Component Acquisition Executive (CAE) designates the MDA to the lowest appropriate level. Further information on these acquisition categories can be found in DoD Directive 5000.2.

C. SELECTED ACQUISITION REPORTS

Selected Acquisition Reports (SARs) are one of the two sources of data for the analysis conducted in this research. " The depictions of cost, schedule, and program performance contained in the SAR provide the most consistent, official track of program management available. The SAR is the logical source of data for calculating cost growth on major procurements (Hough, 1992, p.9)."

SARs were initially used as a tool to internally manage acquisition programs beginning in 1969. In 1975, Public Law 94-106 mandated that SARs be submitted to Congress for all ACAT I or ACAT IA programs (Hough, 1992). As explained in the acquisition category section, the Secretary of Defense can designate a non-MDAP for SAR submittal (DoD 7000.3-G).

A Selected Acquisition Report is a yearly, standardized report that summarizes a MDAP's cost, schedule, and performance data for that year. The program office personnel prepare the SAR for their program and then forward the SAR to the Office of the Secretary of Defense (OSD) for submission to Congress. Congress uses SARs to supervise the progress of MDAPs. These reports provide early warning of possible cost or schedule problems that could concern Congress.

A SAR contains 19 sections and instructions on the proper method to input data for each section. Instruction for preparing SARs is contained in DoD 7000.3-G. The sections most pertinent to this research are Section 9 - Schedule, Section 11 - Program Acquisition Cost, and Section 13 – Cost Variance Analysis. The schedule section contains development and current estimates for essential points in the program to include Milestones 0 - III. Section 11 contains program cost data development estimates and current estimates in base-year and then-year dollars. This section also contains information concerning system quantities.

Section 13 provides cost variance information in both current and base-year dollars. The cost variances are divided into the following seven categories.

- Economic
- Quantity
- Schedule

- Engineering
- Estimating
- Support
- Other

The schedule and quantity category variances and SAR Sections 11 and 13 are discussed in more detail in the methodology explanations later in this research. Benefits and limitations of using SAR data for schedule and cost variance analysis are discussed in the next chapter.

D. IMPORTANCE OF CYCLE TIME AND COST REDUCTION

At this time, many circumstances are converging which are increasing the importance of program cycle time and cost variation research. The three main circumstances are the change in threat environment, decreasing defense budget, and the need to modernize existing weapon systems. These circumstances require the DoD to field new systems quickly and upgrade existing equipment within the constraints of a significantly reduced defense budget. Understanding acquisition program cycle time and cost variation, and the relationship between these two important program elements could provide a partial solution to the challenges presented by these convergent conditions.

1. Change in Threat Environment

The current DoD Acquisition Process is structured to solve technical problems based on a stable, known threat. During the era of the Soviet threat, the acquisition of new systems was driven by performance goals. Cost and schedule were dependent variables and were adjusted to ensure that the performance objectives were met or exceeded .(Kaminski, 1997) Cost and schedule considerations were not as important as the exceptional performance required to counter the Soviet Union's military capabilities. The acquisition process operated within an action-reaction system. The U.S. relied on

intelligence assets to ascertain the attributes that the new Soviet systems would possess and to determine a relatively accurate appraisal of when the new system would be fielded. (Kaminski, 1995)

With this intelligence information, the acquisition requirements generation process could determine exactly what performance characteristics our new military systems required and when these systems needed to be operationally fielded. This afforded the acquisition process with a long lead-time to develop the required systems. Also, with the threat of the Soviet Union, the American public was not as concerned with the cost of these systems. As Dr. Kaminski (1995) stated, "In the tradeoffs that were made in those times, performance was the sine qua non of every major defense acquisition program. Cost [and schedule] were a fall out -- dependent variables (p.2)."

However, since the fall of the Berlin Wall, the United States no longer faces a single threat like the former Soviet Union. Since Operation Desert Storm, the U.S. Armed Forces have participated in over 40 contingency operations, worldwide. The future battlefield has become fluid and complex, focusing on peacekeeping operations like Bosnia, Haiti, Somalia, and Kosovo. (Shalikashvili, 1996) Macgregor (1997) states that a revolution in military affairs (RMA) has occurred in this post-Cold War era. RMA alludes to the fact that there has been a great increase in the ability to combine precision strike capabilities with the worldwide growth of information technology.

As mentioned above, the culmination of the Cold War did not bring world peace as people had hoped, in fact, threats to the U.S. have only changed (Perry, 1996). As the former CJCS, General Shalikashvili, states "since the fall of the Berlin Wall 'expect the unexpected' has become the watch-word for the American Armed Forces (p.165)."

Today's United States military forces must be able to quickly react to various and increasingly complex threats. Sanders (1997) states, "in statistical terms, the mean value of our single greatest threat is considerably reduced, however, the variance of the collective threat has increased" (p.1).

Regional confusion, ethnic conflict, and war will probably continue to grow over the next 20 years. American Forces will be called upon to diffuse threats from terrorists, rogue nations, or from leaders of countries who oppress their citizens (Shalikashvili, 1996). International terrorist attacks against American citizens and property have increased yearly by 5% from 25% in 1996 to 35% in 1998. As stated above, this trend is likely to continue (Tenet, 1999).

The average cycle time for DoD Acquisition Programs, program initiation to IOC, is estimated to be 9 to 11 years (White Paper, 1997, p.1). These cycle times, while arguably adequate during the Cold War, are no longer acceptable. The commercial sector is developing technological innovations at a much faster pace. Comparable commercial equipment has a cycle time of 3 to 4 years and the commercial computer sector's technology cycle is between 12 to 18 months (Kaminski, 1997).

One example of a lengthy acquisition cycle problem is the Air Force F-22 Raptor. The decision to develop the F-22 was based on a threat and a Mission Need Statement over a decade old. The aircraft incorporates computer technology at the 386-processor level. This technology is already many levels of magnitude less efficient and effective than computer technology available today at commercial stores. (White Paper, 1997)

Another example is the continuing acquisition of the RAH-66, Comanche Helicopter. The RAH-66's first SAR was in 1985 and the initial planning for the

Comanche was initiated in the early 1980s. The Comanche was originally developed to fight against the Soviet Union. Now 14 years later, the Comanche is still not in production and the threat has dramatically changed.

United States lawmakers have reacted to the reduced threat of the Soviet Union by decreasing both the DoD budget and force structure. Scarborough (1998) has characterized this defense budget decline as the "peace dividend" (p.8). The budget and force structure has been adjusted to reflect this new environment. If the defense budget decrease is the correct course of action is questionable based on the increasingly widespread conflicts (Somalia, Bosnia, Kosovo); however, this debate is beyond the scope of this research.

What is not debatable is the necessity for the DoD Acquisition Process to adjust to the requirements of this new security environment discussed in this section. This new security environment does not afford the luxury to gather detailed intelligence information and then field the newly required system a decade later. "The lives of our soldiers, sailors, Marines, and airman will increasingly depend upon shortened acquisition cycle time. In a global market, everyone, including our adversaries, will gain increasing access to the same commercial technologies base (Kaminski, 1997, p.2)". In today's world, new systems must be fielded to the operational user quickly in a cost-effective manner.

2. DoD Budget Decrease

> Right now DoD's biggest challenge is finding the resources to both keep today's forces ready to fight, while at the same time investing now in future technologies. Our defense budget has been reduced by 40% and it will remain flat for the foreseeable future (Cohen, 1998, p.2).

Over the last 14 years, from 1985 to 1999, the defense budget has steadily decreased. The defense budget has declined from a high of $418.4 billion in 1985 to the current level of $257.3 billion, a 38.5% decrease. The Army defense budget has declined from $108.2 billion to $64.3 billion, a 40.6% decrease.

The decrease in the defense budget is a deliberate strategy to capitalize on winning the Cold War. The billions of dollars cut from the defense budget are used to increase other Government spending and reduce the budget deficit. Government lawmakers are operating in a "zero-sum" environment. The only way to increase one budget account is to decrease another account by the same amount. With the threat of the Soviet Union streaming through the Fulda Gap extremely unlikely, public opinion favors spending tax dollars on public programs; not defense programs. (Doyle, 1998)

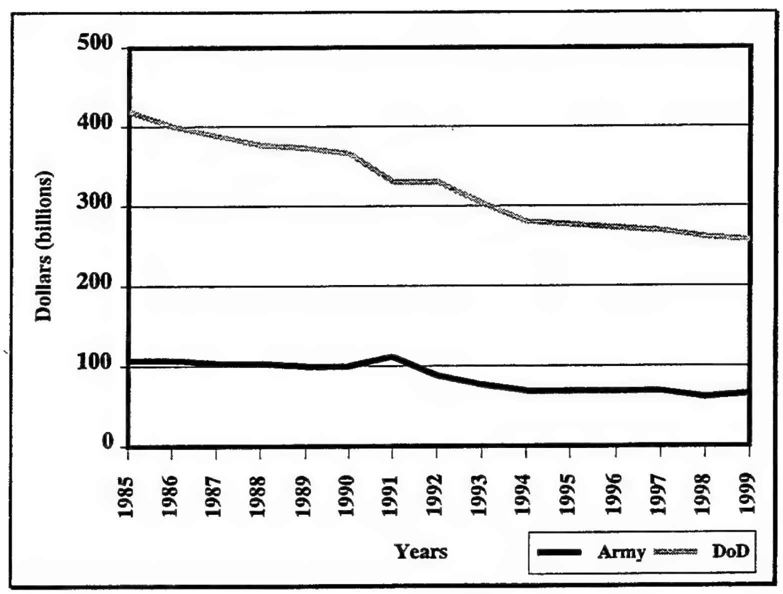

Figure 3: Defense Total Budget Authority

Accounts within the defense budget have also declined sharply. The two most important defense budget accounts for acquisition management are the RDT&E and Procurement accounts. These two accounts are usually called modernization accounts.

Respectively, these two accounts are necessary to conduct research, development, and testing of new acquisition systems and to procure them.

The RDT&E account supports exploratory development and research of new technologies with military potential. Acquisition personnel spend RDT&E dollars on a system's development, testing, and prototypes. The Procurement account supports the production of systems and their components. Procurement dollars are spent on initial spares, and modernization and upgrades of existing systems (Berner, 1993).

During this same 14-year period, the RDT&E account has decreased from $45.1 billion or 10.8% of the overall defense budget to $36.1 billion or 14.0% of the defense budget. The Army RDT&E account has decreased from $6.3 billion to $4.8 billion (Defense Budget Materials, 1999).

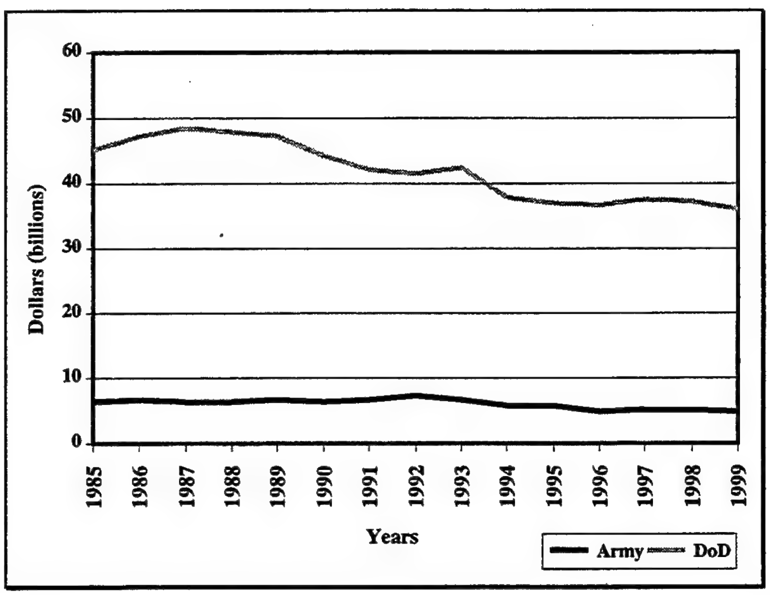

Figure 4: Defense RDT&E Budget Authority

The Procurement account has decreased from $136.4 billion or 32.6% of the overall defense budget to $48.7 billion or 18.9%. The Army Procurement account has

decreased from $25.5 billion or 23.5% of the Army defense budget to $9 billion or 13.9% of the Army defense budget (Defense Budget Materials, 1999).

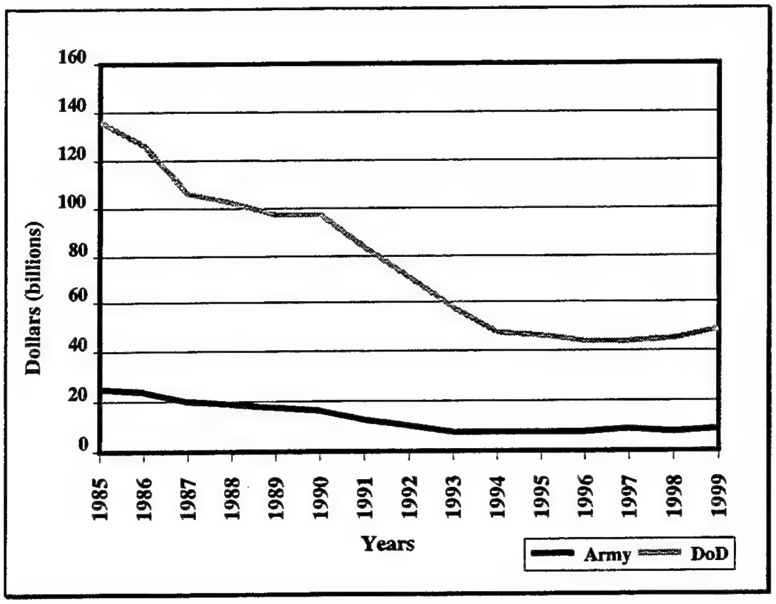

Figure 5: Defense Procurement Budget Authority

The decrease in the RDT&E and Procurement accounts is a deliberate plan within the DoD. The DoD decided to make current readiness the priority. Defense Secretary Perry pledged "to make readiness the first priority, even at the expense of other important uses for the department's resources" (Morrison, 1995, p.1218). Current readiness includes the Operation and Maintenance (O&M) account and the Personnel account. Representative Saxby Chambliss states that, "the looming defense budget problem is a train wreck waiting to happen. There's no answer yet. One answer is to put more money in it... I don't know where it is going to come from but we have simply got to put more money into defense (Schneider, 1999, p.2)."

The majority of the currently proposed defense budget increases, $12 billion for the Fiscal Year 2000 budget, are targeted at immediate needs; pay raises, service member benefits, and readiness (Crock, 1999). The Chairman of the Joint Chiefs of Staff (CJCS),

General Shelton, stated that "The President's spending increases will halt the readiness decline but will not help much with modernization" (Mann, 1999, p.426).

3. Need for Modernization

During the force structure decline, the military was able to delay buying new equipment because existing equipment could be transferred from deactivated units and reallocated to other units. This luxury is complete and the daunting task of modernization must be faced (Shalikashvili, 1996). Pillar 3 of Secretary of Defense Cohen's (1998) new Defense Strategy is "Prepare now for an uncertain future (p.2)." A major goal of this pillar is to maintain a modernization effort to develop new technologically advanced systems and replace existing aging systems. The 1998 Army Modernization Plan has five goals to complete over the next decade. Two of these goals will entail the need for increased RDT&E and Procurement funding. These goals are to "sustain essential research and development and focus technology on Leap-Ahead technology for the Army After Next", and to "recapitalize the existing force (Army Modernization Plan, 1998, p.7)."

The increasing need for military equipment modernization is beginning to receive further recognition. President Clinton has addressed the need for modernization in both the 1997 and 1999 State of the Union Addresses (p.295 & p.230). Marine Corps Commandant General Krulak (1999) stated that, "the modernization shortfall is a 'cancer' (Mann, p.427)." The last Quadrennial Defense Review (QDR) recognized that a detailed procurement plan is needed to ensure the U.S. military could modernize its equipment. This plan endorsed the need to increase Procurement funding to develop new systems and upgrade existing systems. The JCS have stated that the Procurement account needs to increase to a minimum

and sustainable level of $60 Billion / year in order to meet requirements set in the NMS (Fulghum, 1999).

Since 1996, the Procurement account has increased by $4.3 Billion to a level of $48.7 Billion, in 1999. The Procurement account is projected to reach $53 Billion next year and $62 Billion in 2001 (Fulghum, 1999). The General Accounting Office (GAO) is skeptical that these future Procurement increases can be achieved. DoD's modernization plan must overcome two long-lasting defense budget trends. First, since 1965, O&M spending has increased at a comparable rate with the Procurement account. The DoD's modernization plan includes increasing the Procurement account, between 1998 - 2003, while decreasing the O&M account (GAO, 1997). From 1998 to 1999, the O&M account has decreased by $2 Billion while the Procurement account has increased by $3 Billion. However, DoD's ability to maintain this type of relationship for the next 4 years is unclear.

The second defense budget trend is that the Procurement account has mirrored the overall Defense account, since 1965. In order for the modernization plan to succeed, the Procurement account must increase by 43% while the defense budget remains flat (GAO, 1997). From 1998 to 1999, the defense budget has decreased by $3 Billion while the Procurement account has increase by $3 Billion. Again, the DoD's ability to maintain this successful relationship for the next 4 years is questionable.

As General Shalikashvili (1995) stated, "Modernization is tomorrow's readiness (Morrison, p.1218)." In order for tomorrow's service members to accomplish their missions, future readiness must be achieved. The equipment and systems currently used by DoD soldiers are nearing the end of their expected lifetime. Active duty soldiers are flying 35-

year-old bombers and air-lifters, 25-year-old fighters, 40-year-old assault helicopters, and driving 35-year-old trucks. (Morrison, 1995)

These systems will soon need to be replaced with upgraded systems incorporating the newest technology. The military must be able to develop, produce, and field these new systems within the constraints of the reduced defense budget and at an accelerated cycle time required to adapt to the already described ever-changing threat environment.

E. SUMMARY

Chapter II provides a background on the DoD Acquisition Process. The requirements generation process, the acquisition process, the PPBS, and the acquisition categories are discussed in adequate detail to facilitate an understanding of the analysis in Chapter IV and Chapter V. Additional information on these acquisition aspects can be obtained from DoD Directive 5000.2R. SAR information is also provided to familiarize the reader with the primary source of the research data.

This chapter concludes with an explanation of why this research is important in today's changing acquisition environment. Program cycle time and cost variation analysis can provide a partial solution to deal with these three convergent conditions; the new security environment, the decline of the defense budget, and the need for modernization. The Acquisition Process must adjust to the new environment these identified conditions have created. Today's acquisition environment requires the ability to quickly react to numerous, ever-changing, worldwide threats. The Acquisition Process must be able to quickly field systems, within the constraints of the reduced defense budget, before the technology becomes outdated or the threat changes.

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III. CYCLE TIME AND COST VARIATION

Program cost increases and schedule delays are two of the oldest, most prevalent, and most visible problems associated with weapon systems development and procurement (GAO, 1997, p.14).

A. INTRODUCTION

This chapter provides information on the methodologies used to analyze the cycle time and cost data collected for this acquisition program cycle time and cost research. Knowledge of these methodologies will facilitate an understanding of the analysis presented in Chapter IV of this thesis. This chapter also presents a discussion of the benefits and disadvantages of using SAR information for this type of research. Understanding these benefits and disadvantages is important for a complete understanding of the analysis portion of this research document.

In order to understand the methodologies discussed in this chapter and the analysis presented in the next two chapters, three terms must be clearly defined.

- Program - This term refers to a specific effort to provide a new or improved capability that is funded by RDT&E and Procurement appropriations.
- Commodity - Each of the programs in this study are placed into one of five program areas (Tactical missiles, C3I, Helicopters, PGM, and Vehicles). The individual programs are placed in these commodities based on program characteristics, as specified in the CTAT database.
- Group - This term refers to how the programs are sorted for this research. The 35 Army programs are divided into two groups; the full acquisition cycle group and the modification group.

B. CYCLE TIME VARIATION

This section of Chapter III identifies and discusses the source of the cycle time data for the identified Army programs. It also explains the methodology used to analyze the cycle time data as presented in Section B of Chapter IV.

1. Source of Cycle Time Data

The cycle time data used in this research is extracted from the DoD Cycle Time Analysis Tool (CTAT) database. CTAT was developed by TASC, Inc. to provide a tool that facilitates access and portraits DoD acquisition program schedule data. CTAT integrates DoD MDAP and MAIS schedule data from SARs and APBs, and displays this data in terms of the major milestones described in Chapter II. The CTAT includes all DoD programs that have submitted SARs since 1969. This tool facilitates cycle time data analysis by numerous variables. Data can be analyzed and displayed by service, program start year, system category, milestone decision point, and many others. A statistical package can also be added to the CTAT to generate a more detailed statistical analysis of these categories. A complete description of the CTAT can be found in the DoD CTAT User's Guide. A CTAT User's Guide and information about the CTAT can be acquired from the Office of the Under Secretary of Defense for Acquisition.

Instead of using the statistical analysis provided by CTAT, this research extracts the required cycle time data from the raw database. This approach is followed to facilitate merging this cycle time data with cost data extracted directly from the SARs. CTAT provides the means to export the entire database to Microsoft Excel as an Excel spreadsheet. This all-encompassing spreadsheet was initially modified to include only Army programs. Then the Army programs are split into two groups: full acquisition programs and

modification programs. These two groups are further modified to only include programs that incorporated a full acquisition cycle. This means that programs are included in the full acquisition program group only if the program incorporates or plans to incorporate MS I, MS II, MS III, and IOC.

Lastly, this spreadsheet is modified to portrait the selected programs by the five program commodities as shown in Table 1. These modified spreadsheets are shown in Appendix A of this research paper. There are two spreadsheets included in Appendix A. One spreadsheet shows the cycle time data by commodity and by actual milestone date. The second spreadsheet shows the same data; however, instead of milestone date the cycle time data has been converted to months. Table 1 lists the 21 programs included in the full acquisition cycle group by program commodity. For these programs, the current cycle time estimate in the last program SAR is used in this analysis.

Table 1. Program Commodity: Full Acquisition Programs

Tactical Missiles	C3I	Helicopters	PGM	Vehicles
Javelin	AFATDS	AH-64A	ATACMS-BAT	Crusader
Hellfire	AN/TTC-39	RAH-66 #1	Copperhead	M1 Abrams
ATACMS/APAM BL I	SCAMP	RAH-66 #2	SADARM	Bradley
Lance	SMART-T	UH-60A		PLS (FHTV)
Longbow Hellfire	Longbow Apache			

There are two RAH-66 entries because this program was rebaselined in 1990. RAH-66 #1 contains program data from years 1985 – 1990 and RAH-66 #2 contains program data from years 1992 – 1997. Table 2 lists the 14 programs included in the modification group, again by program commodity.

Table 2. Program Commodity: Modifications

Tactical Missiles	C3I	Helicopters	PGM	Vehicles
AGM-114	ASAS	CH-47D	BAT P3I	BFVS/A3 Upgrade
STINGER-RMP	MCS BL III	OH-58D	ATACMS/BAT Block II	M1 Abrams Upgrade
ATACMS/APAM Block 1A			ATACMS/BAT Block IIA	M1A1
				M1A2

2. Cycle Time Analysis Methodology

The cycle time data is analyzed to determine cycle time growth, cycle time percentage growth, and program length. The results of the analysis are presented in Section B of Chapter IV. In order to help explain the cycle time methodology, the data for the Single Channel Anti-Jam Man-Portable (SCAMP) program is used to demonstrate the calculations for each of the three metrics.

Table 3. Cycle Time Data for SCAMP

Program	PrgmStart - IOC	MS I - MS II	MS II - MS III	MS III - IOC
	Months	Months	Months	Months
SCAMP	72	5	45	22
SCAMP	72	5	45	22
SCAMP	72	5	30	37

Each of the above lines represents data from a yearly SAR for the SCAMP program. A program's first year SAR data is the base-year for the cycle time analysis. Also, a program's last submitted SAR data is the current estimate. For this analysis, the word "growth" expresses variance. Positive growth means that cycle time increases and a negative growth means cycle time decreases. All of the calculations in this analysis are in months.

a. ***Cycle Time Growth***

Calculating the cycle time growth is a process of subtracting the base-year cycle time estimate from the current estimate. For the SCAMP program's overall (MS I – IOC) cycle time growth, the following calculation is computed:

Current Estimate	-	Base Year Estimate	=	Cycle Time Growth
72	-	72	=	0

This calculation is computed for each of the phases (MS I – MS II, MS II – MS III, and MS III- IOC). For this program, the overall cycle time growth is 0 because the negative growth from MS II – MS III (-15) and the positive growth from MS III – IOC (15) cancels each other.

b. ***Cycle Time Percentage Growth***

The cycle time percentage growth is calculated using the cycle time growth calculation, shown previously, and then dividing the cycle time growth by the base-year estimate. The calculation for the SCAMP's percentage growth from MS III – IOC is shown below:

Current Estimate	-	Base Year Estimate	=	Cycle Time Growth
37	-	22	=	15

Then, the cycle time growth is divided by the base-year estimate to arrive at the cycle time percentage growth as shown:

(Cycle time growth	/	Base-Year Estimate)	*	100%
15	/	22	*	100%

The SCAMP's percentage growth from MS III – IOC is 68.18%.

The cycle time percentage growth metric is calculated because it is important to understand the degree by which a program varies from the baseline cycle time estimate. However, the cycle time percentage growth metric can be misleading. If a phase (MS I – MS II) has a small base-year estimate (2) and a small cycle time growth (2), then the cycle time percentage growth is 100%. On the other hand, if a phase has a large base-year estimate (20) and a small cycle time growth (2), then the cycle time percentage growth is now only 10%. These programs have a difference of 90% in percentage growth, even though each program experienced the same cycle time growth in months. Appendix A of this report includes the raw data in Excel tables used to calculate this metric.

c. Program Length

The program length (MS I or MS II to IOC) is the actual months required or months estimated to meet IOC, as reported in the final or last submitted SAR. This means actual program length is the length of the original program estimate plus any subsequent growth from that estimate (Drezner, 1990). If a program has not reached IOC as of the last submitted SAR, then the current estimate in the last submitted SAR is used for program length.

C. COST VARIATION

This section of Chapter III discusses the source of the cost data for the identified Army programs. It also explains the methodology used to analyze the data presented in Section C of Chapter IV. The methodology is based on the Institute for Defense Analysis (IDA) and RAND cost methodologies. These methodologies are presented in the IDA Paper P-2722, *The Effects of Management Initiatives on the Costs and Schedules of Defense Acquisition Programs*, and the RAND paper, *An Analysis of Weapon System Cost Growth.*

The most significant difference is the method of adjusting for quantity changes within a program's acquisition cycle. This research in this document uses the quantity cost variances as reported by the program office personnel in each program SAR. Both IDA and RAND use internal methods to calculate their own cost numbers based on quantity change. Each uses a method based on cost quantity curves.

The research conducted in this document, IDA, and RAND analyze each SAR to ensure that affects of program baseline changes and arbitrary changes are adjusted for in the current estimate. Exactly what adjustments are made to the cost numbers are not explained in minute detail in the IDA and RAND reports due to the number of programs included in their research. However, a detailed description of cost adjustments is provided in Appendix D of this document. Appendix D provides enough detail to recalculate each cost growth factor. Further research can use Appendix D to recreate the cost growth factors in this document or adjust these numbers based on different assumptions or research objectives. Table 9 in Chapter V provides a comparison between cost growth factors for programs common to all three research efforts.

1. Source of Cost Data

The data source for the selected Army programs is the individual program SARs. For the 34 identified programs, 296 individual yearly SARs are analyzed. For the cost analysis, there are only 34 programs because the RAH-66 is analyzed as a whole program. This is also the case in the Chapter V analysis. The required cost data is extracted from SAR sections 11 and 13.

a. SAR Section 11

SAR Section 11 is called "Program Acquisition Cost". This section addresses a program's total cost separated into Development (DEV), Procurement (PROC), and Construction costs. More recent SARs change the Development (DEV) cost to RDT&E cost. Throughout the rest of this document, these two terms are interchangeable when referring to costs. However, Development (DEV) cost must not be confused with Development Estimate (DE). These dollar amounts are provided in base-year dollars and escalated to then-year dollars. For each of these costs, there is an initial program estimate and a current estimate (CE). The initial program estimate can either be a planning estimate (PE) or a development estimate (DE).

The PE is estimated at the time of program initiation approval (MS I). This estimate accounts for the operational characteristics, technical characteristics, schedule, and acquisition costs. The PE will be utilized until the DE becomes the program baseline. The DE is estimated at the time of Full Scale Development (FSD), MS II, and should also account for the same factors as the PE. Once either of these estimates is established, only the approval of the Assistant Secretary of Defense Comptroller (ASD(C)) can change the established baseline. (DoD 7000.3-G)

As mentioned above, SAR Section 11 also includes a CE in base-year and then-year dollars. The CE is the most recent cost forecast for a program's operational and technical characteristics, the program schedule, and the program acquisition cost required to procure the approved program quantities (DoD 7000.3-G). The initial estimate (PE or DE) can then be compared to the CE to determine the amount of program cost growth. This is further explained in the cost growth methodology section of this chapter. SAR Section 11

contains additional information such as program quantity, unit cost, design-to-cost goals, foreign military sales data, and nuclear cost as applicable. These information categories are not discussed because they are not pertinent to this research.

b. SAR Section 13

SAR Section 13 is called "Cost Variance Analysis". This section contains cost information concerning any cost variances between the initial cost estimate (PE or DE) and the current estimate. The cost variances are separated into the seven categories as presented in Chapter II. Prior to approximately 1982, the cost information in this section contained only the base-year cost variance with a column that showed escalation costs for each variance category. After approximately 1982, the format changed and the cost variance is shown in both then-year and base-year dollars.

The cost growth information (base-year or then-year) in this section is divided into two categories. These categories are Previous cost variances and Current cost variances. The Previous cost variance category includes the aggregate cost variances from the first program SAR to the previous reporting period. The Current cost variance category only includes cost variances incurred during the current SAR reporting period. As an example, use the yearly 1990 SAR for a program. For this program, the Previous cost variance would include all cost variances in aggregate from program start (1st SAR) to 1989. The Current cost variance category would include all cost variances for the 1990 reporting period. To obtain the total cost variance for this program, the Previous cost variance are added to the Current cost variance. This total is shown in the Total Changes row of SAR Section 13. Only two of the seven cost variance categories are pertinent to this research: Schedule and Quantity.

2. Cost Data Analysis Methodology

This section provides the methodology for calculating the cost growth variables used in the cost analysis in Chapter IV and the regression analysis in Chapter V. Prior to defining the cost variables, three cost issues need to be discussed. These issues are changing baseline estimates, adjusting for quantity cost variance, and explaining the use of cost factors instead of reporting cost growth in dollars.

a. Cost Variance Analysis Issues

The objective of this research is to quantify cost growth from program start to IOC or last SAR submission, and then determine its relationship to schedule growth. Due to this objective, the PE and the DE are incorporated in the same sample group. If a program only has a PE, such as the RAH-66 Comanche, then the PE is used as the cost baseline. If a program initiates with a PE and then converts to a DE at MS II, such as the AH-64 Apache, then the DE is used for the cost growth calculations. If a baseline's (PE or DE) cost changes arbitrarily then the initial baseline continues to be utilized.

Another baseline estimation problem that could occur is when a cost baseline (PE or DE) is updated to a different constant dollar year, for example, changing from reporting in constant 82 base-year dollars to constant 89 base-year dollars. In this case, the constant base-year in the last SAR is used. Error could enter the calculations based on the program office's inflation calculations. However, this error could be compounded by attempting to convert the new constant base-year cost amounts and the cost variance amounts back to the original base-year.

Both the cost analysis and the cycle time growth relationship to cost growth includes analysis incorporating the total cost growth unadjusted for quantity changes.

However, these analyses also include cost growth adjusted for quantity changes. In order to maintain a consistent baseline, all quantity adjustments are normalized to the baseline quantity. The method for accomplishing this normalization procedure is taken from RAND cost growth research (Hough, 1992). This procedure uses the reported cost quantity variance in the cost variance analysis section of the SAR. The quantity cost variance is subtracted from the total program cost variance to obtain a cost variance adjusted for quantity. Further explanation of this normalization procedure and an example are provided in the cost growth variables definitions. Alternate methods (using cost-quantity curves) are available; however, this method is selected because it is the most straightforward, and because the quantity cost variance is based on initial estimate cost-quantity curves (DoD 7000.3-G). An explanation of the affects of quantity change is presented in Chapter V.

The third issue is the use of cost growth factors, or cost growth percentages, instead of the more straightforward cost growth expressed in dollars. Cost growth factors are used in order to compare cost growths between different programs. As mentioned previously, program costs are expressed in both then-year and constant base-year dollar amounts in each SAR. This allows a researcher to calculate the cost growth within a program without the need for inflation adjustment. However, this does not apply to a cost growth comparison between different programs because each program usually has a different constant base-year.

Usually, a program's first SAR year is selected as the constant base-year for the program. In order to compare a program's cost growth across different constant base-years, a cost growth factor is calculated which represents a percentage cost growth. The cost growth factor is defined as the current estimated cost divided by the initial estimated

cost. A cost growth factor of 1 means that there is no cost growth. A cost growth factor exceeding 1 means that the program has experienced an increase in program cost, and a cost growth factor less than 1 means the program has experienced a reduction in program cost. (Peck, 1962) If a cost growth factor is calculated to be 1.19, then that program has experienced a 19% increase in program cost.

b. SAR Cost Data Adjustments

The cost numbers expressed in a program's last SAR can not be extracted without additional consideration to the program's history. Numerous events could occur during the life of a program that could affect a program's cost numbers. A program's cost numbers need to be adjusted for these program changes. The following explanations provide an overview that describes adjustments made to programs included in this research. A more detailed presentation of cost adjustments is provided in Appendix D.

The first step that must be completed is ensuring that the cost data in the final year SAR is correct. The DoD 7000.3-G SAR guidance states that the Previous Changes plus the Current Changes in the SAR cost variance section should equal the Previous Changes in the next year SAR. In other words, the Total Changes amount in the SAR cost variance section should equal the subtotal in the Previous Changes section of the next year's SAR. "Corrections to Previous Changes will be shown as Current Changes. For example, if the previous Other Changes of +15 should have been classified as Estimating, the Current Changes would show -15 for Other and +15 for Estimating (DoD 7000.3-G, p.3-1)." In some cases, the Total Changes amount in a SAR did not equate to the sum of the Previous Change amounts and the Current Change amounts. This problem occurred in the

1983 SAR for the Bradley in which the Total Changes only included the sum of the Current Changes.

In some of the program SARs, the Total Changes from the previous year SAR do not equal the Previous Change subtotal in the next year's SAR. Some of the variance categories seem to be adjusted arbitrarily. In these cases, the change explanations are analyzed to either allow the adjustment if there is an explanation or to adjust the cost variance if there is no reasonable explanation. An example of a reasonable explanation occurs in the RAH-66 Comanche program. There is a discrepancy between the 1989 and 1990 SARs in the schedule variance category. The Previous Changes section of the 1990 SAR includes +145 in the schedule variance that did not appear in either the of the1989 SAR's Previous Changes or Current Changes sections. The variance explanation shows that the +145 is added to the schedule variance due to DoD direction to rebaseline the program. Even though this amount should have been incorporated in the current variance change section, the explanation makes sense and the cost is not adjusted.

The M1 Abrams program's last SAR is 1991; however, the cost information for this program is extracted from the 1985 SAR. The 1985 SAR cost data is used because after 1985 the M1 modifications, M1A1 and M1A2, are combined into the M1 SAR. The schedule and performance data is separated in the SAR but the cost information is combined. There is no way to separate the cost data based on the program SARs. This situation also occurs in the ATACM/BAT program because after 1993 the program upgrades; P3I, ATACM/BAT Block II, and Block IIA, are included in a combined cost. The AGM-116 Hellfire cost data is extracted from the 1991 SAR because the Hellfire Optimized Missile System (HOMS) Hellfire II is included in the cost data in 1992 and 1993.

The SADARM program is adjusted to only include the cost data from the SADARM 155mm projectile. Up to 1995 the program also included cost information for a MLRS SADARM rocket; however, this part of the program was cancelled in 1995.

The Longbow AH-64 program data does not include the 1996 and 1997 SARs because these SARs contain production estimates. This program data includes both the fire control system and the necessary airframe modification costs. This program is included in the C3I commodity because the DoD approved CTAT database classifies this program as avionics. Since this is the only program with this classification, this program is included with the C3I commodity for this research.

The Bradley program is adjusted to reflect when the actual Bradley program started. From 1973 to 1977, this program is the XM-23, Mechanized Infantry Fighting Vehicle. In 1978, the program incorporates two systems; the XM2, Infantry Fighting Vehicle and the XM 3, Cavalry Fighting Vehicle. In 1979, the program actually became the Bradley. The Bradley program cost is adjusted to only incorporate cost associated with the Bradley. This is accomplished by subtracting the cost amounts in the Previous Change Section of the 1979 SAR from the final year SAR's Current Estimate. Further explanations of cost growth factors and an example are presented in the cost variable definition section that is discussed next.

c. Cost Variable Definitions

This section defines all of the cost growth variables associated with the cost growth analysis presented in Chapters IV and V. As mentioned previously, the cost growth numbers used in this analysis are extracted from SAR Sections 11 and 13. The initial basis for these cost growth numbers is a program's final year SAR that is adjusted for errors and

program changes as explained in the previous section, and in detail in Appendix D. As with the cycle time data, the cost data is extracted from a programs last SAR. If a program as not yet reached IOC, then the current cost estimate in the last SAR is used in the analysis.

To facilitate the definition of these cost growth variables, the 1992 SAR cost data for the AH-64 Apache is used to provide example calculations. These examples use the unadjusted 1992 SAR cost data for the AH-64A. For this reason, the factors calculated in this section do not match the AH-64 cost growth factors presented in Appendix B.

Table 4. 1992 SAR Section 11 Cost Data for the AH-64 Apache

Program Acquisition Cost	Development Estimate	Current Estimate
RDT&E ($)	609.4	731.3
Procurement ($)	1283.0	3142.1
Construction (MILCON)	0	32
Ops and Maint (O&M)	0	0
Total FY72 Base-Year $	1892.4	3905.4
Escalation ($)	1897.4	7839.4
Total Then-Year ($)	3789.8	11,744.8

Table 5. 1992 SAR Section 13 Cost Data for the AH-64 Apache

	RDT&E $	PROC $	MILCON $	Total $
Development Est	609.4	1283.0	0.0	1892.4
Previous Changes				
Economic	-	-	-	-
Quantity	-	541.6	-	541.6
Schedule	94.6	46.2	-4.6	136.2
Engineering	27.6	62.4	-	90.0
Estimating	63.2	818.6	36.6	918.4
Other	-80.9	-	-	-80.9
Support	17.4	391.4	-	408.8
Subtotal	121.9	1860.2	32	2014.1
Current Changes				
Economic	-	-	-	-
Quantity	-	-	-	-
Schedule	-	-	-	-
Engineering	-	-	-	-
Estimating	-	-	-	-

Other	-	-	-	-
Support	-	-1.1	-	-1.1
Subtotal	-	-1.1	-	-1.1
Total Changes	121.9	1859.1	32	2013.0
Current Estimate	731.3	3142.1	32	3905.4

As shown, the dollar amounts in Table 4 correspond to the dollar amounts in Table 5. Table 5 explains the variance between the development estimate and the current estimate in terms of the seven cost variance categories. The cost variances are shown in terms of Development, Procurement, and Construction. The constant base-year dollar estimate plus the previous cost changes and current cost changes equals the current base-year dollar estimate. Each SAR also contains a cost variance section like Table 5 that presents the cost variance in terms of then-year dollars. Each of the following nine cost variables are explained using the AH-64 Apache cost data as presented above.

- TCGF: Total Cost Growth Factor - The TCGF represents the total cost percentage growth from the initial estimate (PE or DE) to the current estimate unadjusted for quantity cost variance. The following is an example of the formula to calculate TCGF. In this example, the AH-64 program experienced a total cost growth of 106% not 206%. Need to remember that 100% of the 206% is due to the initial estimate.

  TCGF = Current estimate / Initial (PE or DE) estimate

  TCGF = (3905.4 / 1892.4) = 2.06

- DCGF: Development Cost Growth Factor - The DCGF represents the total RDT&E cost growth from initial estimate (PE or DE) to the current RDT&E

estimate unadjusted for quantity change. The following is an example of the formula to calculate DCGF.

DCGF = Current RDT&E estimate / Initial RDT&E estimate

DCGF = 731.3 / 609.4 = 1.2

- PCGF: Procurement Cost Growth Factor - The PCGF represents the total PROC cost growth from initial PROC estimate (PE or DE) to the current PROC estimate unadjusted for quantity change. The following is an example of the formula to calculate PCGF.

  PCGF = Current PROC estimate / Initial PROC estimate

  PCGF = 3142.1 / 1283.0 = 2.45

- TCGFA: Total Cost Growth Factor Adjusted - The TCGFA represents the total cost growth from initial estimate (PE or DE) to the adjusted current estimate. The current estimate is adjusted for Quantity cost variance as described previously. The following is an example of the formula to calculate TCGFA. In this calculation, the sum of the Previous Quantity cost change and the Current Quantity cost change is always subtracted from the current estimate. If cost increases due to a quantity change then the Quantity cost variance should be subtracted from the current estimate to adjust for quantity. If cost decreases due to a quantity change then the Quantity cost variance should be added to the current estimate. In this calculation, if the Previous Quantity cost variance plus the Current Quantity cost variance amount is negative, then subtracting a negative number results in the Quantity cost variance being added to the current estimate.

TCGFA = (Current Estimate - (Previous Quantity variance + Current Quantity variance)) / Initial estimate

TCGFA = (3905.4 - (541.6 + 0)) / 1892.4 = 1.78

Comparing TCGFA to TCGF demonstrates the affect that quantity change, within a program, has on cost growth analysis. Cost growth decreases by 28% after adjusting for quantity.

- DCGFA: Development Cost Growth Factor Adjusted - The DCGFA represents the total RDT&E cost growth from initial RDT&E estimate (PE or DE) to the adjusted current RDT&E estimate. The current RDT&E estimate is adjusted for Quantity cost variance as described previously. The following is an example of the formula to calculate DCGFA.

DCGFA = (Current RDT&E estimate- (Previous RDT&E Quantity cost variance + Current RDT&E Quantity cost variance)) / Initial RDT&E estimate

DCGFA = (731.3 - (0 + 0)) / 609.4 = 1.20

In this instance there is zero quantity cost variance associated with the RDT&E estimate so the DCGFA is the same as the DCGF.

- PCGFA: Procurement Cost Growth Factor Adjusted - The PCGFA represents the PROC cost growth from initial PROC estimate (PE or DE) to the adjusted current PROC estimate. The current PROC estimate is adjusted for Quantity cost variance as already described. The following is an example of the formula to calculate PCGFA.

PCGFA = (Current PROC estimate - (Previous PROC Quantity cost variance + Current PROC Quantity cost variance)) / Initial PROC estimate

PCGFA = (3142.1 - (541.6 + 0)) / 1283.0 = 2.03

In this instance, there is a decrease in the Procurement cost growth of 42% after adjusting for quantity changes.

- STCGF: Schedule induced Total Cost Growth Factor - The STCGF is the amount of program cost growth that is attributed to schedule changes. This variable is calculated with the following formula.

  STCGF = Initial estimate + (Previous Schedule cost variance + Current Schedule cost variance) / Initial estimate

  STCGF = 1892.4 + (136.2 + 0) / 1892.4 = 1.07

- SDCGF: Schedule induced Development Cost Growth Factor - The SDCGF is the amount of RDT&E cost growth that is attributed to schedule changes. This variable is calculated with the following formula.

  SDCGF = Initial RDT&E estimate + (Previous RDT&E Schedule cost variance + Current RDT&E Schedule cost variance) / Initial RDT&E estimate

  SDCGF = 609.4 + (94.6 + 0) / 609.4 = 1.16

- SPCGF: Schedule induced Procurement Cost Growth Factor - The SPCGF is the amount of PROC cost growth that is attributed to schedule changes. This variable is calculated with the following formula.

  SPCGF = Initial PROC estimate + (Previous PROC Schedule cost variance + Current PROC Schedule cost variance) / Initial PROC estimate

SPCGF = 1283.0 + (46.2 + 0) / 1283.0 = 1.04

D. SAR DATA FOR CYCLE TIME AND COST ANALYSIS

There are both benefits and disadvantages when using SARs as the data source for this type of research. This section of Chapter III will discuss both the benefits and disadvantages of the SAR data. Mistakes and misleading conclusions could arise if a working knowledge of these benefits and disadvantages is not understood.

1. Advantages of Using SAR Data

Four advantages of using SAR data for cycle time and cost variation analysis are discussed in this section. These advantages are that SARs contain the most cycle time and cost information in one location, relational databases, SARs are now in electronic format, and inflation adjustments.

a. Cycle Time and Cost Data

The biggest advantage of using SARs as the data source for cycle time and cost research is that all ACAT I and ACAT IA programs must submit a SAR to DoD at least yearly. Each program's SAR should report any significant schedule or cost changes and the reason for these changes. Section 13 of the SAR portraits cost variation due to schedule variation. This cost data is expressed in both base-year and current-year dollars. SARs are one of the few official Government documents that provide relatively consistent and accurate information on program cost, schedule, and performance data (Drezner, 1993).

b. Relational Databases

Another advantage of using SAR data is that relational databases containing SAR data are being developed. The CTAT is one example of an interactive database, based on SAR data, designed to facilitate analysis of program cycle time. The Defense System

Cost Performance Database, also based on SAR data, was developed by RAND in order to analyze program cost variation. It is probably only a matter of time before a relational SAR database is developed that incorporates all three important aspects of a program; cost, schedule, and performance.

c. Electronic Format

Currently all available SARs have been transferred to CD, which greatly increases the access to all SAR data. Prior to the SAR CDs, all paper SARs were on record in Washington, D.C. In order to access all of the SARs, a researcher had to travel to Washington and spend a significant amount of time extracting the required data from filed paper reports. Now a researcher can request the CDs and thus access any program SAR from their home location. This computer access also greatly decreases the time requirements for gathering SAR data. A slight drawback is that these CDs are classified as SECRET. In order to use these SAR CDs, a researcher must have a SECRET clearance and access to a secure processing facility.

d. Inflation Adjustments

A fourth advantage of SAR data is that post-1974 SARs report cost in both current and base-year dollars. This allows cost research to be conducted either with or without the effects of inflation. If a researcher wants to show how cost growth affects the overall budget then inflation should be taken into account. If a researcher wants to analyze program cost growth only due to program inputs then inflation should not be incorporated. (Hough, 1992)

2. Disadvantages of Using SAR Data

Four disadvantages of using SAR data for cycle time and cost variation analysis is discussed in this section. These disadvantages are selecting a baseline, exclusion of some costs, incomplete database, and inflation adjustments.

a. Baseline Selection

The greatest disadvantage of using SAR data is the selection of a baseline. As discussed previously, a baseline must be selected in order to compare current cost estimates. Three baselines can be selected from the SAR data; the planning estimate (PE), the development estimate (DE), and the production estimate (PdE). The PE is associated with MS I, the DE is associated with MS II, and the PdE is associated with MS IIIa. Each acquisition program does not have all of these baselines. RAND conducted a cost growth study in 1993 that incorporated 278 DoD-wide programs. Of these 278 programs only 38 included a planning estimate. (Drezner, 1993)

Since the DE is the most prevalent, the majority of cost research uses the DE as the baseline. However, selection of the DE as a baseline does not ensure consistency. A DE can change during the life of a program due to previous error, restructuring, or in some case seemingly arbitrary change. In these cases a researcher must use their best judgement to minimize adding error to the baseline. (Hough, 1992)

b. Cost Exclusion

Another problem with the SAR database is that not all costs are included in the SAR. Contractors sometimes pay a portion of the RDT&E effort in order to win a contract. In addition, if the program is being procured under a firm-fixed-price contract,

then any cost over the agreed upon price is entirely paid by the contractor and it is not included in the SAR. (Hough, 1992)

A recent example of this potential problem is the F-22 Rapter already mentioned in Chapter II. This Air Force Program is currently experiencing cost growth problems in the billion-dollar range. In order to appease Congress and demonstrate confidence in their cost management goals, Lockheed Martin agreed to produce the first two shipments of planes with a fixed-price contract. (Schneider, 1999) This seems to be a good arrangement for the Government because if cost problems continue then Lockheed Martin will absorb them. However, this is a problem when conducting cost research because the cost growth over the fixed-price contract will not be submitted in the SARs.

c. Incomplete Database

If a program is designated as "highly sensitive classified (black program)" then that program is excluded from submitting SARs. Usually these black programs incorporate cutting-edge technology and require immediate fielding. These two aspects of a black program could lead to significant cost growth; however, this growth is unable to be incorporated into cost growth studies. (Hough, 1992)

Some program SARs are still classified which excludes their cost data from being utilized in this type of research. An example of this problem occurred in this research. The first three SARs and the sixth SAR for the Lance program are still classified, although these SARs are over 30 years old. A related problem occurred when extracting cost data for modification programs. Sometimes a separate SAR is not submitted for modifications, the information is just included in the original program SAR. An example encountered in this research is the M1 Abrams tank. The M1A1 and M1A2 modifications are included in the

original M1 SARs. These SARs separate both schedule and performance data for the M1, the M1A1, and the M1A2 programs. However, the cost data for these same programs is not separated in the SARs. This problem also occurred in extracting cost data for the ASAS, MCS, Stinger RMP, and ATACMS modification programs.

d. Inflation Adjustments

The last disadvantage of using SAR information that is addressed is inflation adjustments. As discussed in the advantages section, since 1975 SAR data is presented in current and baseline dollars. However, prior to 1975 all costs were reported in current dollars. Efforts to calculate a base year cost based on inflation for these programs (1969 - 1974) have been difficult sometimes resulting in negative base year cost changes. Most studies just delete these SARs from the cost growth research (Hough, 1992).

The key to this section is understanding the SAR advantages and disadvantages and then developing a methodology that minimizes the disadvantages. The effects of all of these disadvantages can not be entirely deleted, and a researcher must use good judgement in developing their methodology. It is also important to completely explain any assumptions and judgements made during the research. This will ensure readers understand exactly what the data analysis is representing.

E. SUMMARY

This chapter provides information on the sources for the cycle time and cost data, the CTAT and SARs respectively. The methodologies are discussed in detail to explain the process used to analyze the cycle time and cost data as presented in Chapter IV. Understanding these methodologies is necessary to fully comprehend the analysis results as presented in Chapter IV and Chapter V.

This chapter also thoroughly discusses both the advantages and disadvantages of using SAR data for this type of variation analysis. Knowledge of these advantages and disadvantages is important for understanding both the cycle time and cost methodologies, and the analysis results presented in Chapter IV and Chapter V.

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IV. CYCLE TIME AND COST VARIATION ANALYSIS

> An unreasonably long acquisition cycle - ten to fifteen years for our major weapon systems... is a central problem from which most other acquisition problems stem: It leads to unnecessarily high cost of development... It leads to obsolete technology in our fielded equipment... (Packard Commission, 1986).

A. INTRODUCTION

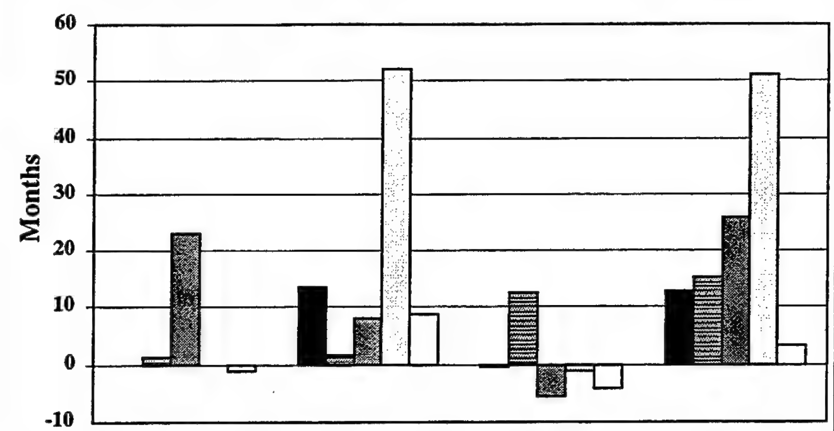
This chapter provides a statistical analysis of Army acquisition program's cycle time and cost variation. Cycle time and cost data is analyzed by commodity (Tactical Missile, C3I, etc) within each of the two program groups; full acquisition programs and modification programs. Data is also analyzed by comparing these two groups. The purpose of this chapter is to provide an understanding of the overall cycle time and cost growth trends as captured by the SAR data.

B. ANALYSIS OF CYCLE TIME VARIATION

This section presents the results of analyzing the cycle time data from the CTAT. The analysis in this section is divided into four parts. This section's first part provides the results of analyzing the full acquisition programs. The second part of this section analyzes the cycle time data from the modification programs, and the third part compares the full acquisition programs to the modifications concluding with a comparison of program lengths. The final part of this section provides a correlation analysis of the cycle time data.

1. Full Acquisition Cycle Programs

As mentioned, each of the programs in this group have a full acquisition cycle; MS I, MS II, MS III, and IOC. Programs that did not incorporate one or more of these milestones are excluded from this analysis in order to retain a homogeneous data grouping.



Commodity	MS I - MS II	MS II - MS III	MS III - IOC	MS I - IOC
Tactical Missiles	0	13.6	-0.6	13
C3I	1.4	1.6	12.4	15.4
Helicopters	23	8.25	-5.5	25.75
PGM	0	52	-1	51
Vehicles	-1.25	8.75	-4.25	3.25

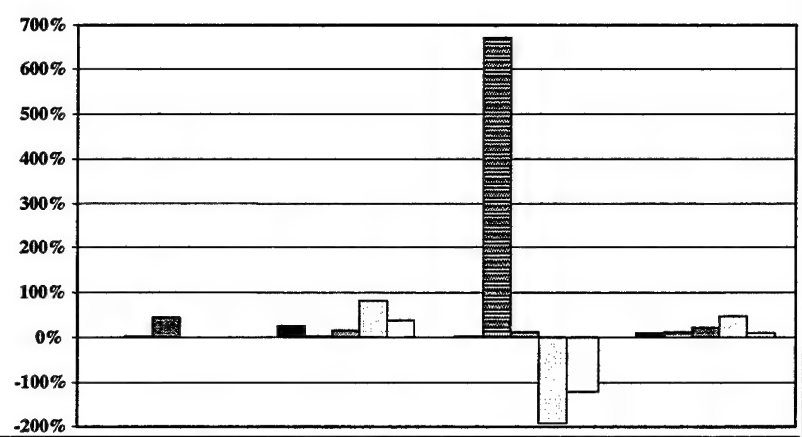
Figure 6: Average Growth by Programs Commodity

The previous figure shows the average cycle time growth by commodity for the full acquisition program group. This group of 21 Army programs has a total cycle time growth (MS I - IOC) of 411 months or 34.3 years. The average growth (MS I - IOC) for these programs is 19.6 months or 1.6 years. Two of the group commodities, PGM and Helicopters, exceeded the average growth of 19.6 months with average growths of 51 and 25.8 months respectively.

The interval between MS II to MS III, Phase II, has the greatest growth of 300 months which is 73.9% of the overall total cycle time growth of 411 months. Phase II is the only phase in which each commodity has a positive cycle time growth. As shown in Figure 6, PGM has the greatest average growth in this phase, 52 months. This average growth is not due to an outlyer program. The variance for the three PGM programs is only 7 with a standard deviation of 2.6.

All of the commodities in Phase I have a growth of +- 1 month except for the Helicopter commodity. The Helicopter commodity has an average cycle time growth of 23 months. This deviation from the rest of the commodities is due to the RAH-66 program. Both the RAH-66 #1 and the RAH-66 #2 have large Phase I cycle time growths of 43 and 48 months respectively. The other two programs in the helicopter commodity, the AH-64A and the UH-60A, have cycle time growths of 1 month and 0 months respectively. Of the 21 programs in this group, only three programs besides the RAH-66 have positive cycle time growths in Phase I. The Longbow AH-64 program has the next largest Phase I growth of 5 months. Fifteen of the twenty-one programs have 0 cycle time growth in this phase.

In Phase III, four of five program commodities have a negative growth, with C3I being the only commodity that demonstrates a positive growth. Of the five C3I programs, SMART-T is the only program with negative growth, 1 month. The other four C3I programs have positive cycle time growths ranging from 4 to 32 months in Phase III.



Commodity	MS I - MS II	MS II - MS III	MS III - IOC	MS I - IOC
Tactical Missiles	0.00%	25%	3.79%	10.24%
C3I	2.34%	3.20%	671%	12.82%
Helicopters	44.81%	16.45%	13.46%	20.11%
PGM	0.00%	81.19%	-192%	45.95%
Vehicles	-1.64%	36.81%	-111.46%	10.04%

Figure 7: Average Percentage Growth by Programs Commodity

Figure 7 represents the average percentage growth for Army programs in the full acquisition group. Each program commodity has an overall positive average percentage growth (MS I - IOC). Cumulatively, programs in this group have a total percentage growth of 347% with an average of 17.8%. Two program commodities, PGM and Helicopters, exceed the average percentage growths with growths of 45.9% and 20.1%, respectively. Each commodity also has a positive percentage growth in every phase except for PGM and Vehicles in Phase III.

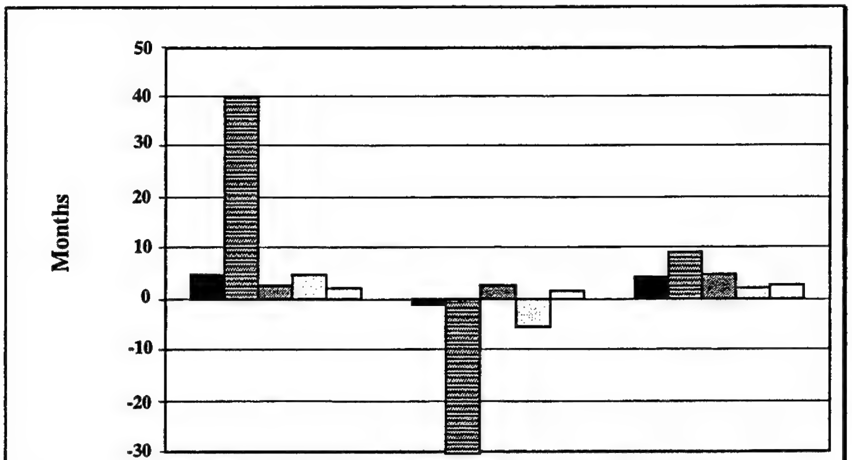
Phase III has the largest average percentage growth of 114.5% and this phase also has the greatest variation. The C3I commodity has a positive average percentage growth of 671% while the PGM commodity has a negative average percentage growth of 192%. These large variations are due to a single program in each of the commodities. As an example, in the C3I program commodity, the AN/TTC-39 program has a percentage growth of 3200% because the original estimate for Phase III was zero months and the actual time was 32 months.

As with the average growth, each program commodity in Phase I has a very small average percentage growth, +-2%, except for the helicopter commodity. This commodity has an average percentage growth of 44.8% again due to the RAH-66 program. In Phase I, RAH-66 #1 has a percentage growth of 134.4% and the RAH-66 #2 program has a percentage growth of 42.9%. The other two programs in this commodity, the AH-64A and the UH-60A, have percentage growths of 2% and 0%.

2. Modifications

As with the full acquisition cycle group, each of the programs in this group has a full acquisition cycle; MS II, MS III, and IOC. Programs that did not incorporate one or more of

these milestones are excluded from this analysis in order to retain a homogeneous data grouping.



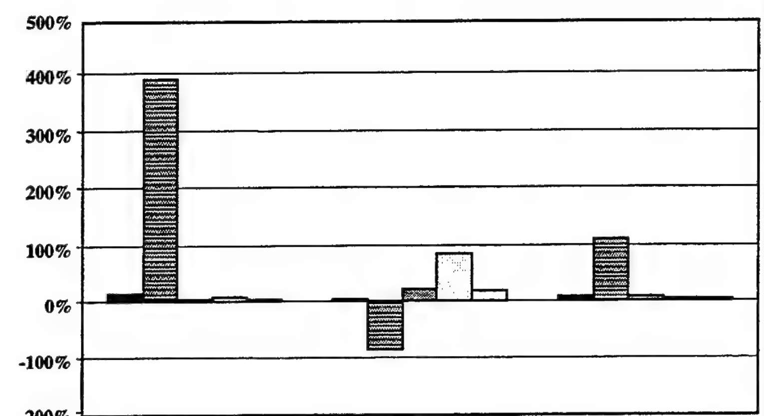
Commodity	MS II - MS III	MS III - IOC	MS II - IOC
■ Tactical Missiles	5.0	-1	4
▤ C3I	39.5	-30.5	9
▨ Helicopters	2.5	2.5	5
□ PGM	5	-5.33	2
□ Vehicles	2	1.25	2.75

Figure 8: Average Growth by Programs Commodity (Modifications)

The previous figure shows the average cycle time growth by commodity for the modification program group. This group of 14 Army programs has a total cycle time growth (MS II - IOC) of 57 months or 4.8 years. Each program commodity has an overall positive cycle time growth and the average overall growth (MS II - IOC) for these programs are 4 months. Two of the group commodities, C3I and helicopters, exceed the average growth of 4 months with average growths of 9 and 5 month respectively.

Phase II has the largest cycle time growth, 120 months, and the largest average growth of 9 months. The majority of the positive growth, 79 of 120 months or 66%, is driven by the C3I commodity. Within this commodity, the MCS BLIII modification accounted for 60 of the 79 months of growth.

Phase III has a negative cycle time growth, 70 months, and a negative average cycle time growth of 5 months. As with Phase II, the C3I commodity program group accounted for the majority of the cycle time growth, 61 of the 70 months or 87% of the negative growth. Within this commodity, the ASAS BLII modification accounted for 51 of the 61 months of negative growth.



Commodity	MS II - MS III	MS III - IOC	MS II - IOC
Tactical Missiles	14.15%	4.84%	8.00%
C3I	391.38%	-86.40%	111.09%
Helicopters	5.29%	21.86%	8.62%
PGM	9.13%	84.44%	3.98%
Vehicles	5.69%	17.01%	4.09%

Figure 9: Average Percentage Growth by Program Commodity (Modifications)

The above figure represents the average percentage growth for the Army programs in the modification group. Each program commodity has an overall positive average percentage growth (MS II - IOC). Cumulatively, programs in this group have a total percentage growth of 291.7% with an average of 20.8%. Only one program commodity, C3I, exceeds the average with an average percentage growth of 111.1%. Each commodity has a positive percentage growth in every phase except for the C3I commodity in Phase III.

As with the average growth, C3I demonstrates the most percentage growth variability. In Phase II, the C3I commodity has an average percentage growth of 391.4%.

This positive growth is due to the MCS BLIII program, which has a percentage growth of 750% due to a 60-month positive growth from an estimated baseline of 8 months. The rest of the program commodities in this phase have a percentage growth range between 5% and 14%.

Phase III has a positive average percentage growth of 14.8%. In this phase, the C3I commodity and the PGM commodity groups cancel each other. The C3I group has a negative average percentage growth of 86.4%. The PGM group has a positive average percentage growth of 84.4%. The positive growth for the PGM commodity is misleading. Only the ATACMS BAT BLII program in this commodity has a positive growth, 400%. The other two programs, the ATACMS BAT P3I and the ATACMS BAT BL IIA, have negative percentage growths of 66.7% and 80% respectively.

3. Comparison of Full Cycle Programs and Modifications

This section compares the full acquisition cycle time data with the modification cycle time data. This section contains a graph of the average growth comparison by phases and the average percentage growth comparison by phases. Additional graphs comparing the full cycle programs and the modification programs can be found in Appendix C. These graphs compare the cycle time data by both program commodity and by acquisition phase.

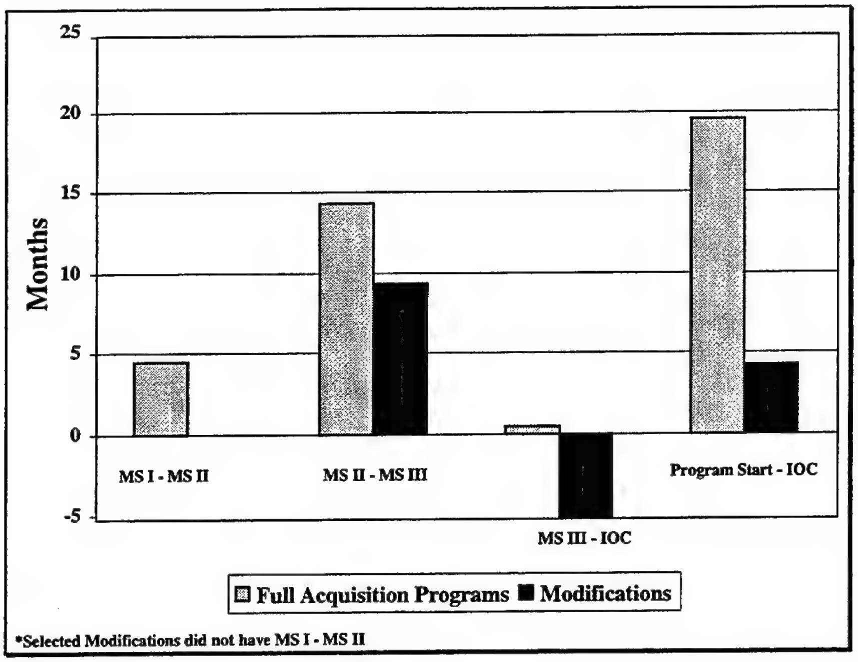


Figure 10: Average Growth Comparison

As figure 10 shows, only the modification group in Phase III has a negative average growth. The negative average growth occurs because three of the five modification commodities (C3I, PGM, and Tactical Missile) have negative growth in this phase. The C3I commodity has the greatest negative average growth of 30.5 months. Phase III also has the least amount of average growth for the full cycle group, .81 months. All of the full cycle commodities have a negative average growth in this phase except for C3I. The C3I commodity has an average growth of 12.4 months.

Phase II shows the greatest average growth for both of the program groups. The full cycle group has an average growth of 14.3 months, which is 73% of the overall total program growth. All of the five program commodities in the full cycle group have positive average growth in this phase. All of the commodities have less than 10 months growth except for PGM and Tactical Missiles which have 52 months and 13.6 months growth respectively.

In Phase II, the modification group has an average growth of 9.2 months, which exceeds the overall total growth for this group. This situation occurs because of the negative growth in Phase III. As with the full cycle group, all of the modification program commodities have positive growth in this phase. All of the commodities have less than 10 months growth except the C3I commodity, which has 39.5 months growth.

Overall, both groups have positive average growth from program start to IOC. The average program growth for the full cycle group is 19.6 months which is almost five times the average growth of the modification group. Within the full cycle group, PGM demonstrated the most average growth (52months) while vehicles showed the least amount of average growth (3.3 months). Within the modification group, C3I demonstrated the most growth (9 months) while PGM showed the least growth (2 months). All of the commodities in both groups have positive average growth from program start to IOC. For each commodity, the full cycle average growth is greater than the modification average growth. The greatest discrepancy , between the full cycle and modification schedule growth, occurs in the PGM commodity. The PGM full cycle growth is 52 months compared to 2 months for the PGM modification group. The commodity with the closest average growths is the vehicle commodity. The vehicle full cycle average growth is 3.25 months compared to the modification average growth of 2.75 months.

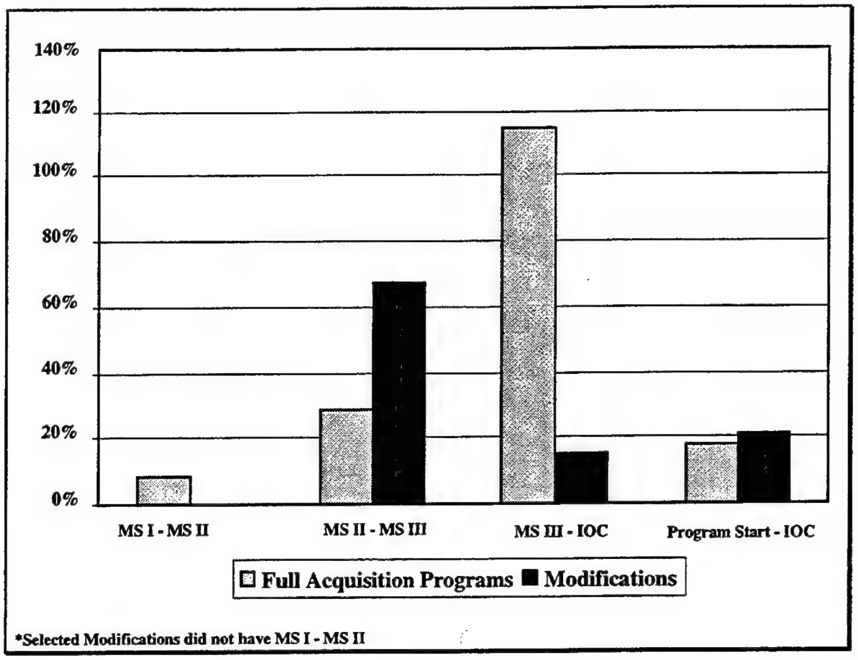


Figure 11: Comparison of Average Percentage Growth

Initially this graph may not seem to make sense because the full cycle average percentage growth in Phase III is much larger than the overall full cycle average percentage growth. However, the graph is correct because the average percentage growths in each phase are not additive. The AN/TTC-39 program in the full cycle C3I commodity is used as an explanatory example. In Phase III, the AN/TTC-39 has a percentage growth of 3200% because the program grew from 0 months to 32 months. However, the overall percentage growth for this program is only 22.9%. This occurs because a negative growth of 8 months in Phase II means this program has 24 months of growth compared to a 105-month baseline.

In Phase II, the modification group has a greater average percentage growth than the full cycle group. The modification group's average percentage growth is driven by the C3I commodity, which has an average percentage growth of 391.4%. The other four commodities in the modification group have average percentage growths below 15%. By

comparison, the full cycle C3I commodity only has a 3.2% average percentage growth in this phase.

In Phase III the data is reversed, the full cycle group has a much greater average percentage growth than the modification group. However, as in Phase II with the modification group, this average percentage growth is driven by the C3I commodity, which has an average percentage growth of 671%. By comparison, the C3I commodity in the modification group has a negative average percentage growth of 86.4%.

Overall, the modification group has a 3% greater average percentage growth than the full cycle group. Each of the program commodities in both groups has an overall average percentage growth of 20% or less except for two commodities. The C3I commodity in the modification group has an average percentage growth of 111.1% and the PGM commodity in the full cycle group has an average percentage growth of 45.9%.

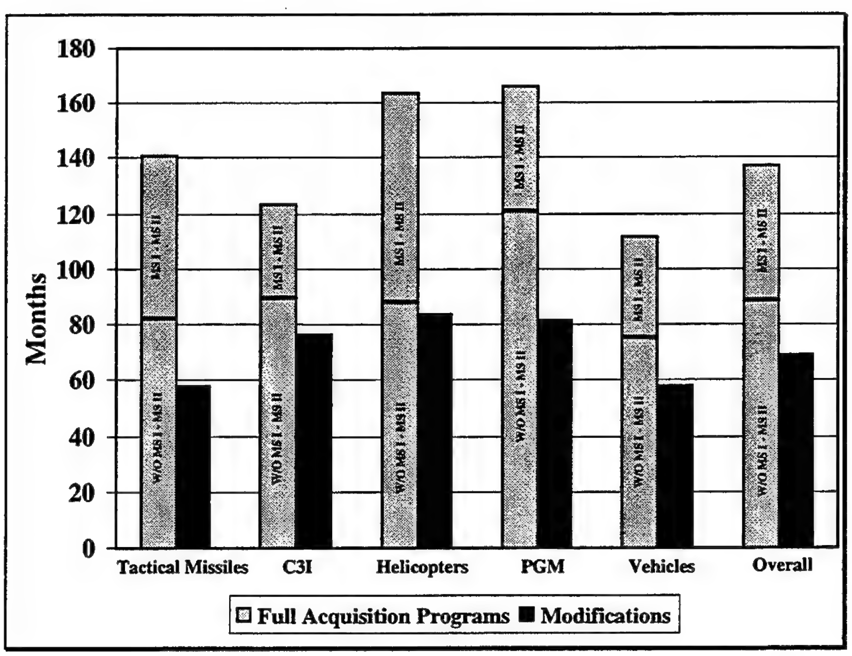


Figure 12: Army Acquisition Program Average Length

All of the full acquisition cycle programs have longer program lengths than their modification program counterparts. The full cycle programs have an average length of 137.2 months or 11.4 years and the modification programs have an average length of 69.6 months or 5.8 years. The average length of the full cycle program is double that of the modifications. Even if Phase I is deleted from the full cycle program length, these programs still have an average program length of 87.9 months or 7.3 years. This is still 18 months longer that the modification programs.

The PGM and Helicopter commodities have the longest program lengths in both the full cycle and the modification groups. The Tactical Missile commodity has the greatest difference in length between the two groups, 82.5 months or 6.8 years. The PGM commodity has the greatest difference in length between the two groups when Phase I is deleted, 39.4 months or 3.3 years. The Helicopter commodity has the least difference between program lengths when Phase I is deleted, only 4 months.

4. Cycle Time Correlation Analysis

This section presents data on the correlation between cycle time growth and original estimated program length, and between cycle time percentage growth and original estimated program length. Correlation between two variables is represented by the coefficient of correlation (r). The value of (r) can range from –1, which represents perfect negative correlation, to +1 which represents perfect positive correlation. A coefficient of correlation of 0 shows that there is no relationship between the two variables. (Levine, 1998)

The next two figures show how cycle time growth (months) correlates to estimated program length. Figure 13 shows the correlation of cycle time growth to the full cycle program's estimated program length. The correlation coefficient (r) is only 0.0725 for the

full cycle programs. This demonstrates that there is very little correlation between estimated program length and cycle time growth for these programs.

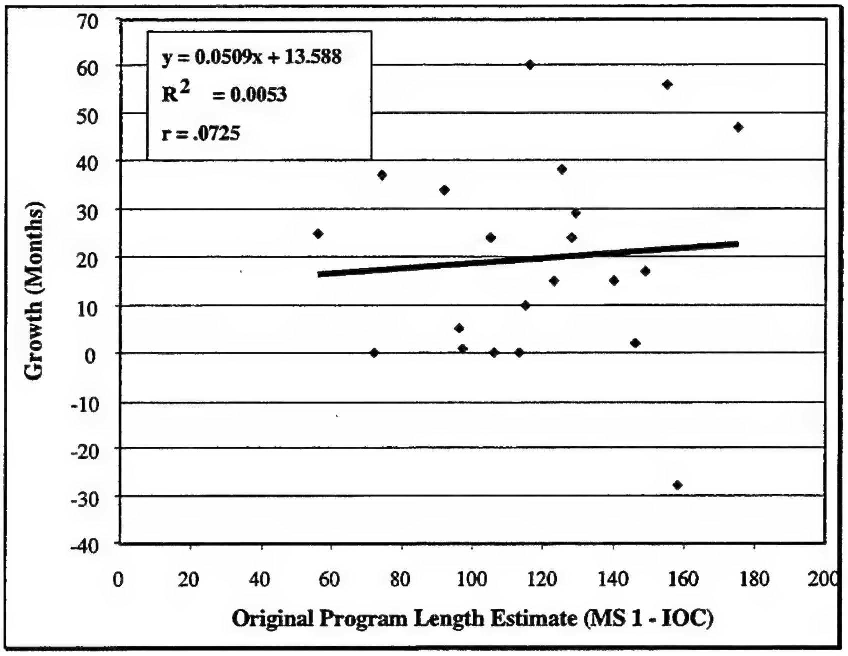


Figure 13: Correlation of Original Estimate to Cycle Time Growth (Full Cycle)

Figure 14 shows the cycle time growth (months) correlation to estimated program time for the modification programs. For the modification programs, the correlation coefficient (r) is -0.6610, which demonstrates that a strong negative correlation exists. This correlation means that cycle time growth for the modification programs tends to decrease as the original program estimated length increases. A correlation analysis is also conducted using the full acquisition cycle programs without the Phase I (MS I - MS II) data. The full cycle program growth from MS II to IOC is correlated to the estimated full cycle program length from MS II to IOC. This analysis is a better comparison to the modification analysis. The result of this analysis is a correlation coefficient (r) of 0.0151, which again shows there is very little correlation between these two variables.

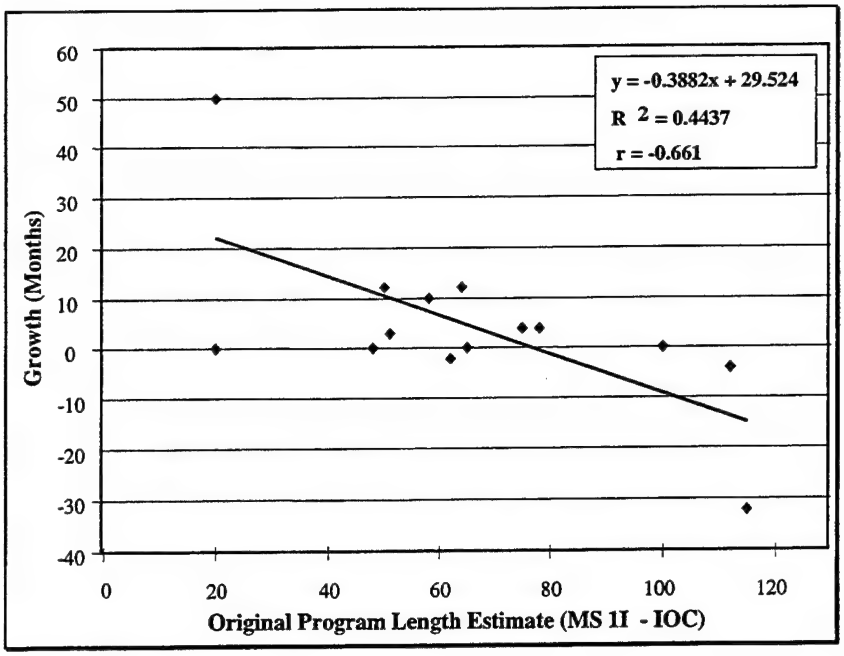


Figure 14: Correlation of Original Estimate to Cycle Time Growth (Modifications)

The following two figures show how cycle time percentage growth correlates to estimated program length. Figure 15 show the correlation of cycle time percentage growth to the full cycle program's estimated program length. The correlation coefficient (r) is -0.2497 for the full cycle programs. This demonstrates that there is very little correlation or relationship between estimated program length and cycle time percentage growth for these programs.

Figure 16 shows the cycle time percentage growth relationship to estimated program time for the modification programs. For the modification programs, the correlation coefficient (r) is -0.5288, which demonstrates that a negative correlation exists. This correlation means that cycle time percentage growth for the modification programs tend to decrease as the original program estimated length increases. This correlation between the percentage growth and estimated program length is expected based on the strong correlation between cycle time growth and the original estimated modification program length.

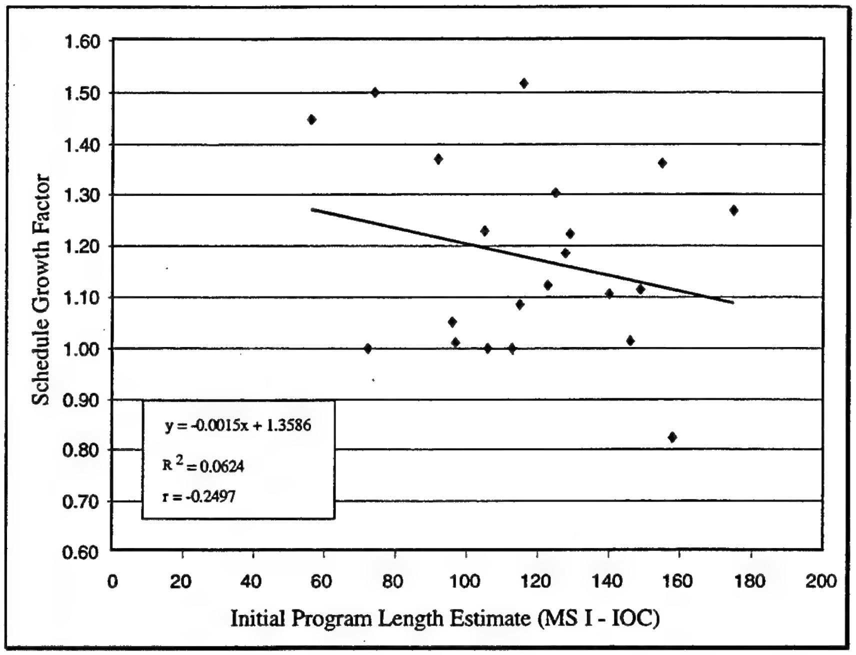


Figure 15: Correlation of Original Estimate to Cycle Time Percentage Growth (Full Cycle)

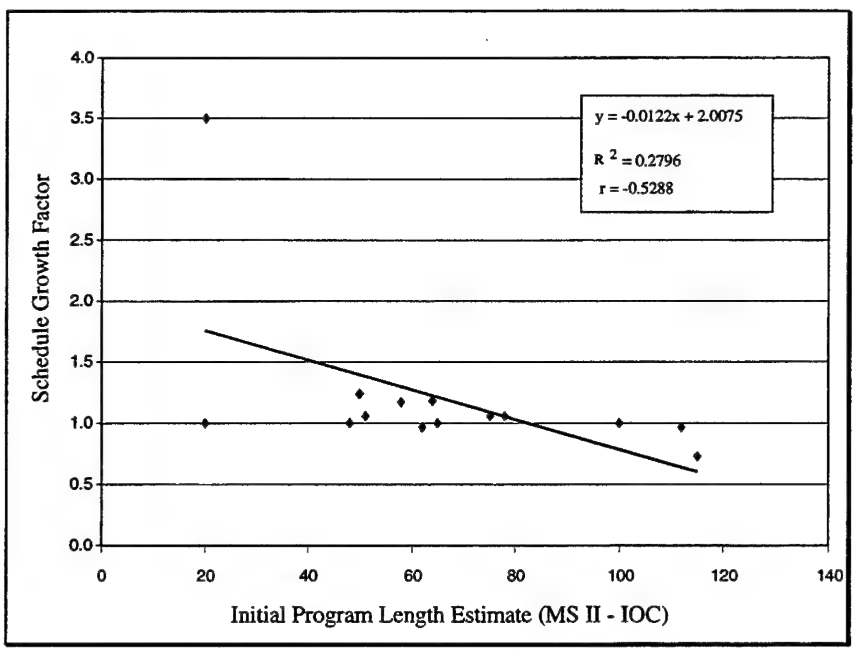


Figure 16: Correlation of Original Estimate to Cycle Time Percentage Growth

(Modifications)

C. ANALYSIS OF COST VARIATION

This section presents the results of analyzing the program cost data extracted directly from the program SARs. The analysis in this section is divided into three parts. The first part of this section provides the results of analyzing the full acquisition program cost data. The second part of this section provides a correlation analysis between program cost factors. The last part of this section compares the full cycle and modification cost data for two of the commodities; Vehicle and Helicopter. The other modification commodities are unable to be analyzed due to problems acquiring and extracting these programs' cost data. These problems are explained in more detail in the second part of this section.

1. Full Acquisition Cycle Programs

The cost data is available for each of the full cycle programs that are analyzed in the cycle time section.

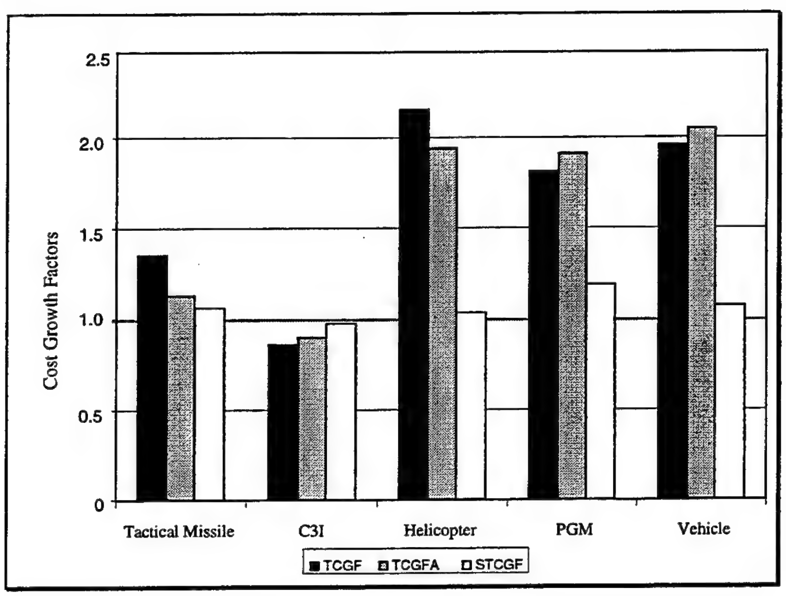


Figure 17: Full Cycle Program Cost Growth Factors

Figure 17 presents the cost growth factors for each commodity in the full cycle group. As mentioned previously, a cost growth factor of 1 means that there is no cost

growth. All of the program commodities experience cost growth and four of the five commodities experience positive cost growth. Overall, these 20 Army programs experience a TCGF of 54.6 %. This unadjusted growth is important from the resource allocation point of view. At program inception, decision-makers at both the DoD and Congressional level make funding decisions based on an initial program cost estimate. Cost increases, for whatever reason, cause funding problems that require funds to be reallocated between programs. The reallocation process causes funding instability for numerous other programs that can lead to inefficient management processes. This affect can snowball leading to cost growth for all affected programs.

Overall, these programs experience a TCGFA of 49.9%. A 1992 cost growth study by the Institute for Defense Analysis (IDA) found a DoD program average cost growth of 47%. The Army programs are only slightly higher than the DoD average. Three of the five commodities experience almost 100% positive cost growth, with the Vehicle commodity the highest at 105.2%. The IDA study also found Vehicles and Munitions (both air and surface launched) to have near 100% program cost growth with 96% and 103%, respectively (Tyson, 1992). The IDA study reported Helicopters at only 42%; however, their study did not include the RAH-66 with its 179% cost growth through 1997.

The program with the highest cost growth is the Bradley program with a cost growth of 329%. Excluding this program, the overall adjusted Army cost growth average falls to 34.9% and the Vehicle commodity cost growth average drops to 29.3%. As Figure 17 demonstrates, program cost growth due to schedule variance is small for each commodity. Overall, STCGF is only 6.2% and schedule accounts for only 14.3% of the adjusted total cost growth in the Army programs. The other 85.7% is attributed to the other five cost

variance categories. The PGM commodity has the greatest schedule induced cost growth of 19.3%.

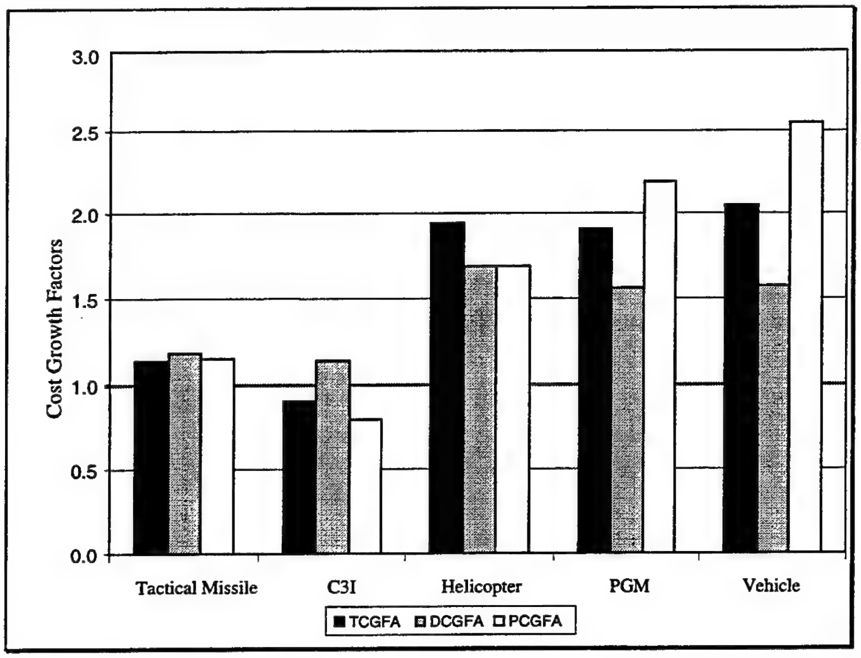


Figure 18: Comparison of DEV, PROC, and Total Cost Growth Factors

Figure 18 shows a comparison of the Development, Procurement, and Total cost growth factors adjusted for quantity. Of the 49.9% TCGFA, DEV cost growth is 38.2% and PROC is 52.1%. In the IDA cost growth study, the DoD average for DEV and PROC is 29% and 56%, respectively (Tyson, 1992). Two of the commodities have a program that does not include a Procurement cost growth factor; RAH-66 in the Helicopter commodity and the Crusader in the Vehicle commodity. These two programs do not have a Procurement cost estimate, as of 1997 SARs.

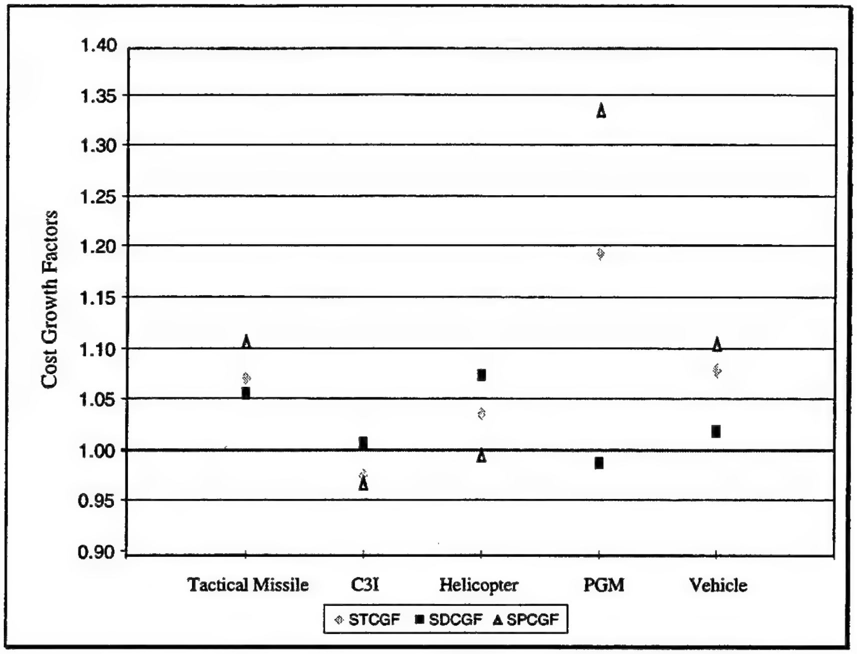


Figure19: Schedule Induced Cost Growth Factors

Figure 19 presents the program cost growth that is due to schedule. As this figure demonstrates, there is no apparent trend in the schedule induced cost growth. The C3I and Helicopter commodities show higher DEV schedule induced cost growth, and the other three commodities show higher PROC schedule induced cost growth. Cost growth can be caused by different factors in DEV and PROC. In DEV, cost growth is usually associated with unforeseen technical problems (Tyson, 1999). DEV cost growth can also be driven by changing requirements. In PROC, cost growth can be associated with production rate changes, quantity changes, or production problems. An explanation of the relationship between quantity changes, production rate changes, and schedule changes is presented in Chapter V.

Figure 20 shows schedule induced program cost variance as a percentage of the program total cost variance adjusted for quantity. Only two commodities have percentages above 15% of the total cost variance adjusted for quantity. This figure demonstrates that

schedule induced cost variance is a small part of the overall adjusted program cost variance. This percentage is much smaller if a program is not adjusted for the effects of quantity. The Helicopter commodity has a negative percentage due to the UH-60 program that has a –23.92 percent. Both the AH-64A and the RAH-66 have positive percentages.

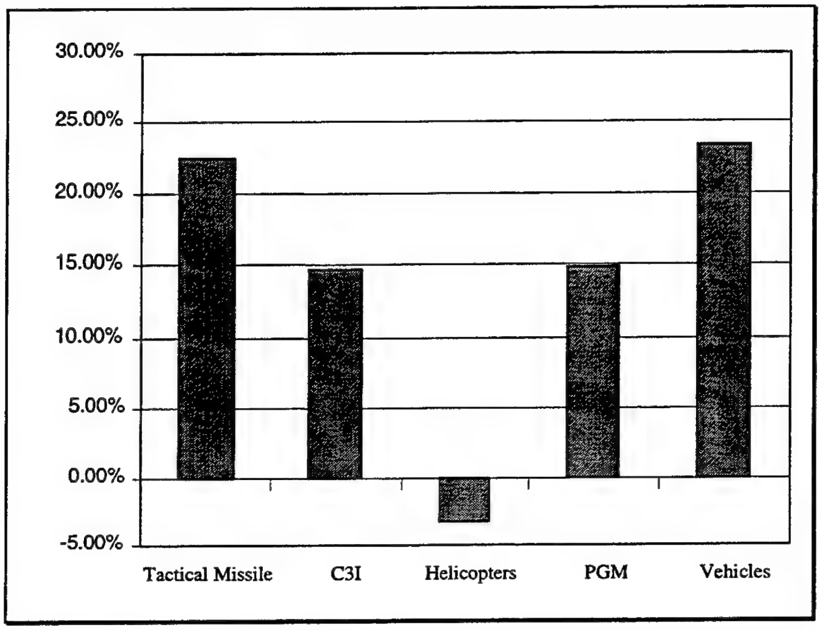


Figure 20: Schedule Induced Cost Growth as a Percent of TCGFA

2. Cost Correlation Analysis

This section presents an analysis of the correlation between program cost related variables. A correlation analysis is conducted between the program's initial cost estimate and TCGFA, and between the program's initial cost estimate and STCGF. This analysis reveals any relationship between the original cost of a program and a program's percentage cost growth that is adjusted for quantity changes. A correlation analysis is also conducted between the year a program is initiated (first SAR reporting year) and TCGFA, and between the year a program starts and STCGF. This analysis reveals any trends in Army program's percentage cost growth over time.

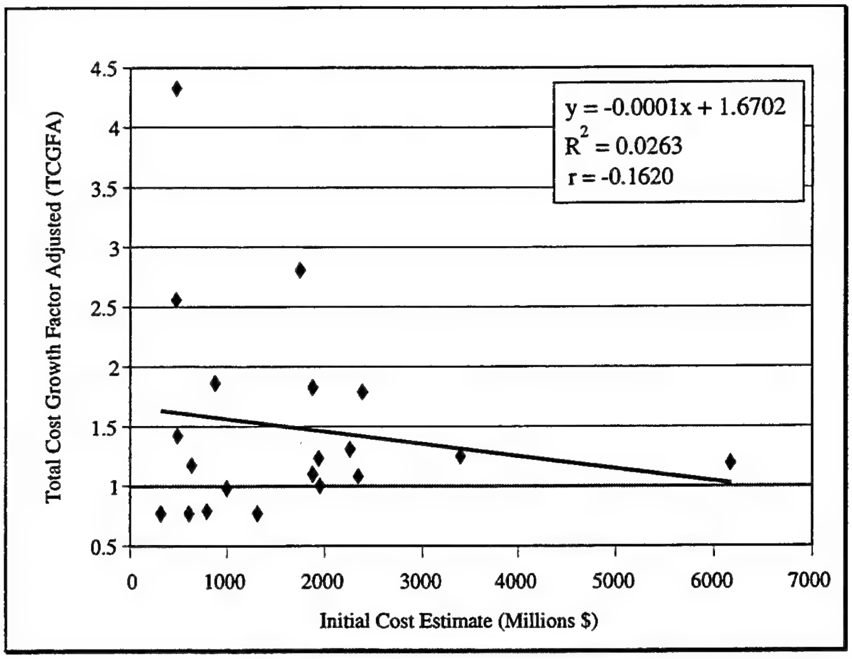


Figure 21: Correlation of Initial Cost Estimate to TCGFA

In this analysis, 15 of the 20 programs have a positive cost growth. Intuitively, it seems that there should be a negative correlation between TCGFA and the original cost estimate. In simple terms, a higher initial cost estimate should result in less cost growth. A correct estimate, which in this case would be higher 75% of the time since 15 of the 20 programs demonstrate positive growth, or a padded cost estimate should mean less percentage cost growth. However, as Figure 21 demonstrates, there is very little correlation between the original cost estimate and TCGFA. This means that the original cost estimate has little influence on a program's percentage cost growth. This relationship is explored in greater detail in the multiple regression analysis conducted in Chapter V.

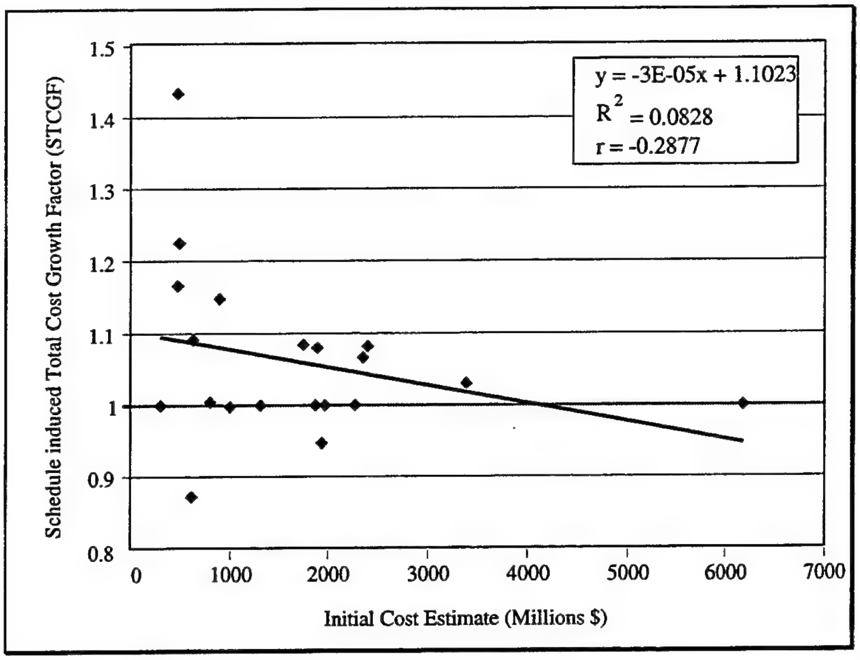


Figure 22: Correlation of Initial Cost Estimate to STCGF

As with Figure 21, there is little correlation between STCGF and a program's initial cost estimate. Figures 23 and 24 show the correlation between the year of program start and two cost growth factors; TCGFA and STCGF. Acquisition personnel would like to see a negative correlation between these two factors. The acquisition community should learn from past mistakes in both cost estimation procedures and management practices. As corrective actions are incorporated into the acquisition process, program cost growth should decrease. However, these two figures demonstrate little correlation between program start and percentage cost growth. There is a negative correlation coefficient between program start and TCGFA; however, it is not statistically significant. These results are not specific to Army programs. An IDA study in 1989 also concluded that throughout DoD there is little correlation between these two factors (Tyson, 1989).

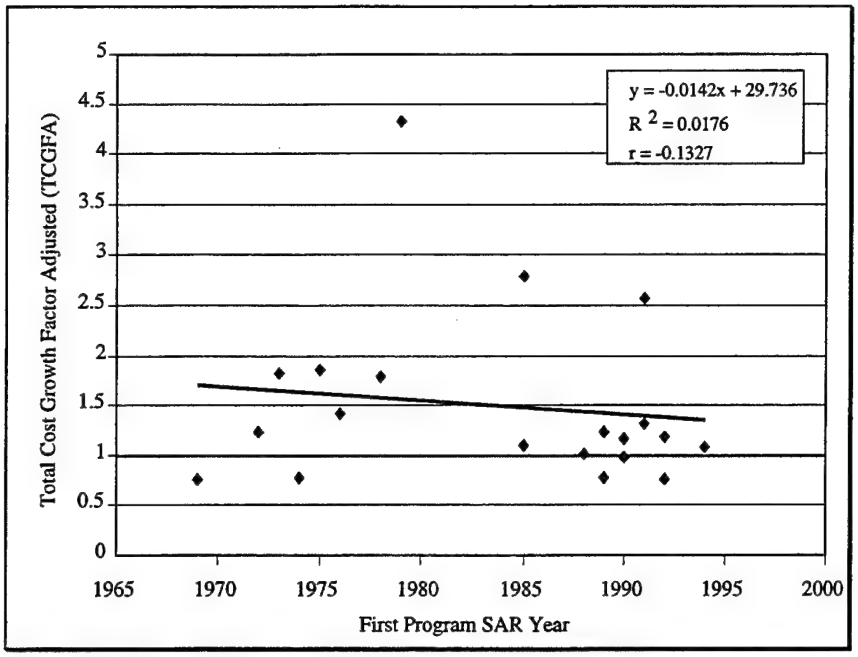


Figure 23: Correlation of Program Start Year to TCGFA

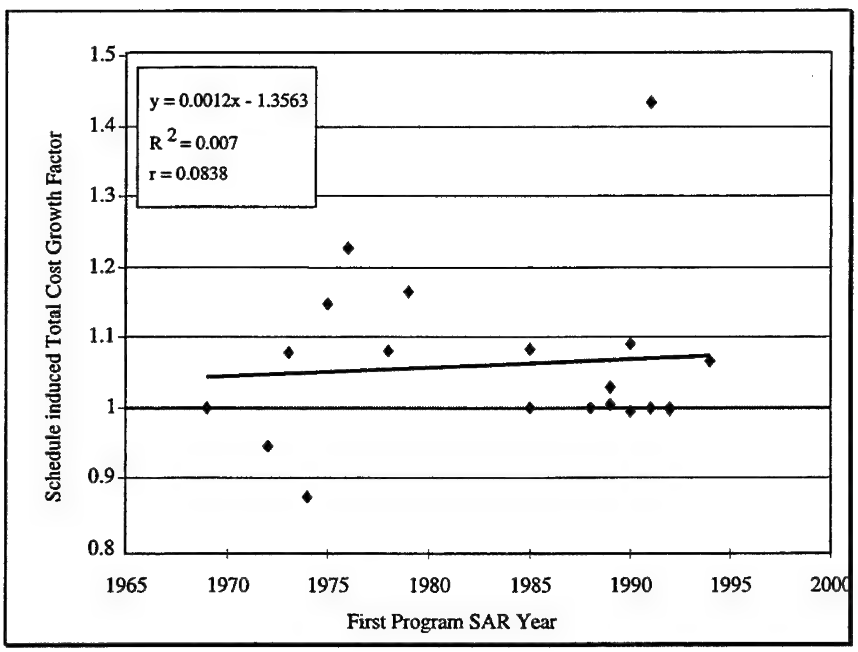


Figure 24: Correlation of Program Start Year to STCGF

3. Comparison of Full Cycle Programs and Modifications

Only two of the commodities can be compared between full cycle programs and modification programs. As explained in the cost methodology section and the SAR disadvantages section, the modification programs in three of the commodities have cost data that is combined with the original program's cost data.

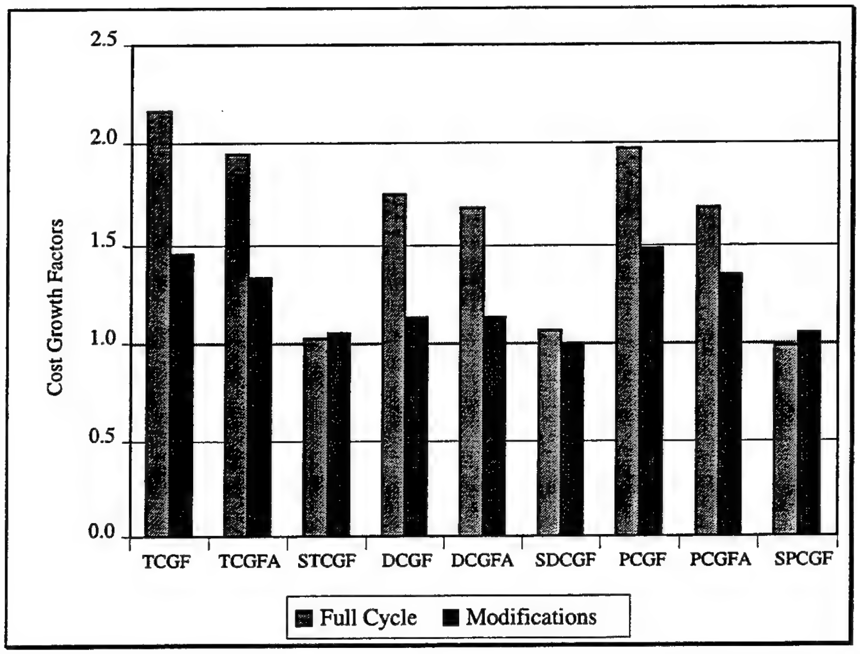


Figure 25: Comparison of Full Cycle versus Modification (Helicopters)

Figure 25 shows that for the majority of the cost growth factors, the full cycle programs have higher percentage cost growth than the modification programs. For the Helicopter commodity only the STCGF and the SPCGF have higher cost growth for modification programs. This means the Helicopter full cycle programs have 61.3% more cost growth than the modification programs.

For the Vehicle commodity, each cost growth factor is higher for the full cycle programs. The full cycle programs have a TCGFA of 2.052 versus a TCGFA of 1.356 for

the modification programs. In this case, the full cycle programs have 69.6% more cost growth than the modification programs.

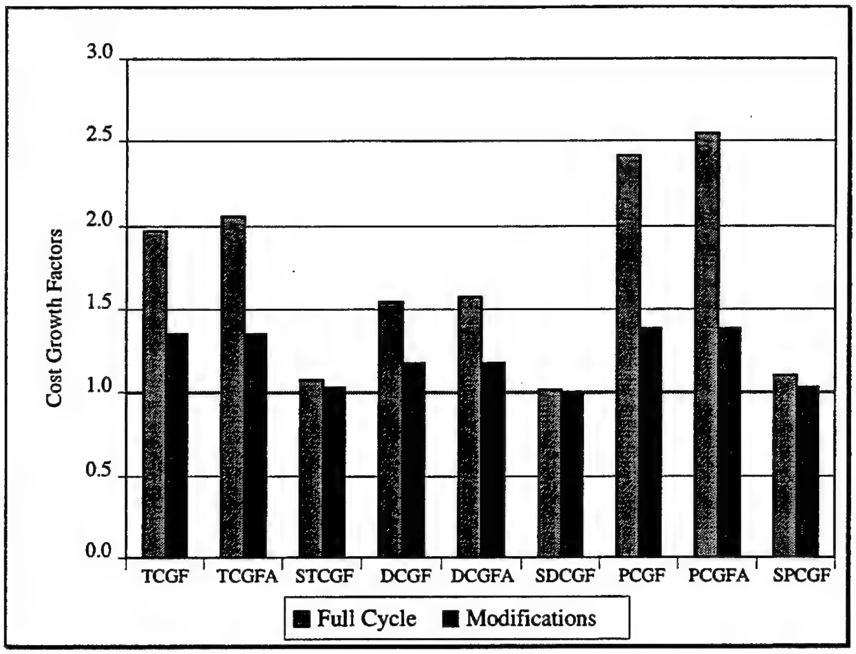


Figure 26: Comparison of Full Cycle versus Modification (Vehicles)

D. SUMMARY

This chapter provides a statistical analysis of Army program's cycle time growth and cost growth information. The cycle time and cost growth data is analyzed for the full cycle programs, the modification programs, and then the data is compared between these two groups. A complete comparison of the cost growth analysis between the full cycle programs and the modification programs is impossible due to an inability to extract modification cost data from the SARs. Summary information for cycle time data is presented in Table 6 and summary information for the cost data is presented in Table 7.

Correlation analysis is also conducted with both the cycle time and cost data. This analysis explores the relationship between program cycle time growth and the original program length estimate for both the full cycle groups and the modification groups. A

strong correlation of –0.661 is revealed in the modification group between original program estimate and cycle time growth.

A correlation analysis is conducted between the program's initial cost estimate and TCGFA, and between the program's initial cost estimate and STCGF. Correlation analysis is also conducted between the year a program is initiated (first SAR reporting year) and TCGFA, and between the year a program starts and STCGF. This analysis is only conducted with the full cycle programs due to the small number of modification programs available for analysis. The original program cost estimate and the year of program start has little affect on TCGFA and STCGF. Thus, none of the cost correlation analyses demonstrates any significant correlation or relationship between the cost variables.

Table 6: Summary of Cycle Time Data

Category	Full Cycle	Modifications
Average Growth	19.6	4.1
Average % Growth	17.8%	20.8%
Phase Largest AVE Growth	Phase II (14.3)	Phase II (9.2)
Phase Largest AVE % Growth	Phase III (114.6%)	Phase II (67.7%)
Commodity Largest AVE Growth	PGM (51)	C3I (9)
Commodity Largest AVE % Growth	PGM (45.9%)	C3I (111%)
Commodity Longest Program AVE Length	PGM (166)	Helicopters (84)
Commodity Shortest Program AVE Length	Vehicles (112)	Tactical Missile (58.3)
Program Largest Growth	SADARM (60)	MCS BL III (50)
Program Largest % Growth	SADARM (51.7%)	MCS BL III (250%)
Program Longest Length	ATACMS-BAT (211)	ATACMS BAT P3I (108)
Program Shortest Length	SCAMP (72)	M1A1 (20)

Table 7: Summary of Cost Data

Category	Full Cycle Cost Growth Factors
Overall Average TCGFA	1.499
Overall Average STCGF	1.062
Commodity Largest TCGFA	Vehicle (2.052)
Commodity Largest STCGF	PGM (1.193)
Program Largest TCGFA	Bradley (4.329)
Program Largest STCGF	SADARM (1.434)
Commodity Least TCGFA	C3I (.897)
Commodity Least STCGF	C3I (.974)
Program Least TCGFA	ATACMS APAM (.759)
Program Least STCGF	AN/TTC-39 (.874)

This chapter provides an analysis of cycle time growth and cost growth independent of each other. Chapter V presents an analysis of how cost growth is affected by schedule growth.

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V. CYCLE TIME AND COST VARIATION CORRELATION

A. INTRODUCTION

This chapter presents information and analysis concerning the interdependence or correlation of program cycle time and cost variation. Section B provides a background of this issue by discussing various conflicting theories on the correlation between cycle time and cost growth. This section concludes with the results of two related research studies. Section C presents a multiple regression analysis of program cycle time and cost correlation for the selected Army programs.

B. PROGRAM CYCLE TIME AND COST RESEARCH

In the last five years, numerous reform initiatives have been proposed to reduce program schedule and cost. The 1994 Federal Acquisition Streamlining ACT (FASA), the 1997 DSAC, and the 1986 Packard Commission set goals to reduce program cycle time by 50%. The 1996 DoD National Performance Review (NPR) set a goal of reducing cycle time by 25%. Cycle time reduction's possible affect on program cost is not addressed by any of these initiatives. (Czelusniak, 1998)

1. Theories of Cycle Time and Cost Correlation

The Under Secretary of Defense (Advanced Technology), Mr. Eash, provided a briefing to the Acquisition Reform Senior Steering Group (ARSSG) on 11 AUG 98. He reiterated that the goal is to reduce cycle time by 25 - 50%. Mr. Eash stated that the longer a program runs (schedule growth), the likelihood of program cost growth increases. "Schedule delays cause cost to grow exponentially by 4 (Eash, 1998)." As mentioned in

Chapter 1, the GAO reports that schedule delays will likely increase program cost; however, the amount of the cost growth is unspecified.

Philip Thomas, the author of *Competitiveness Through Total Cycle Time*, also addresses the affect of a reduced schedule on program cost. Mr. Thomas states that commercial cycle time reduction management concepts should be applied to the defense industry. He believes that these concepts should reduce program cycle time by 50%. This cycle time reduction should result in a comparable 50% reduction in program cost. (Thomas, 1990)

The ideas discussed above pass the common sense test. In theory, program cycle time and cost should be interrelated. Let's first begin with development cost and discuss the relationship hypothesized by Peck and Scherer in 1962 (p.497).

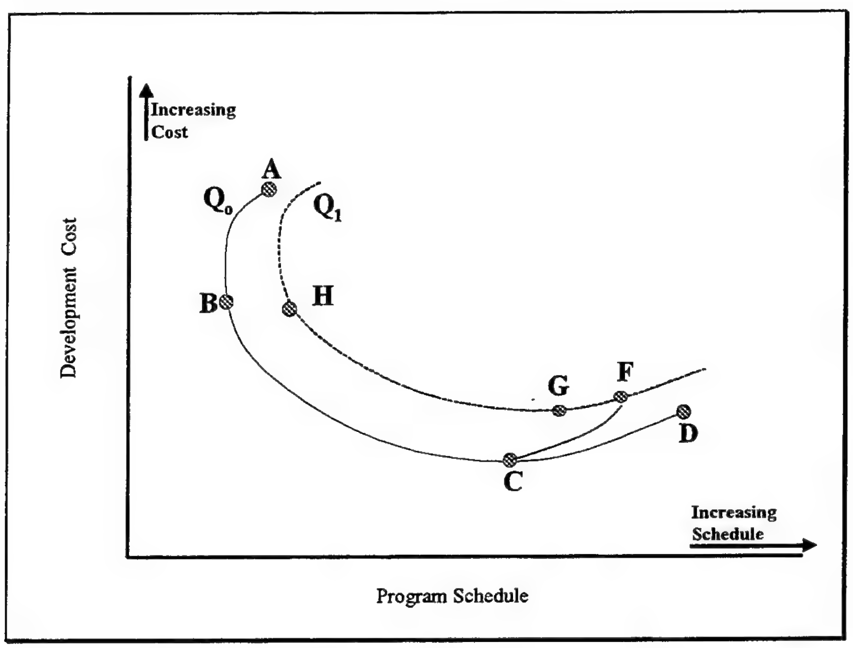

Figure 27: Theoretical Program Schedule versus Development Cost Curve

Development cost efficiency would exist, on a cost vs. schedule curve that represents alternative combinations of cost and schedule that achieve a particular program

performance goal. Within the efficient arc B-C, Point C exists that minimizes development schedule and cost (Peck & Scherer, 1962). Moving to the right of Point C would increase cost and schedule, and be an inefficient combination of these program factors. This inefficiency could be due to mistakes, inefficient management, or previously unknown and unexpected conditions. As the schedule continues to increase, the problems compound, the program becomes riskier, and the slope of the curve increases representing accelerated cost growth. The extreme right slope of the curve increases because larger schedule growths are probably due to increasingly difficult problems. As schedule growth increases, the program will begin to receive oversight attention. Oversight personnel could direct the program to increase testing to solve the problem, which would increase cost. The oversight personnel could also begin to reduce funding, until the problem is solved, leading to program stretchout also increasing program cost.

Moving along the curve to the left, from Point C towards Point B, increases cost; however, schedule is reduced and the combination of schedule and cost is still efficient. Moving to the left, to reduce schedule, requires additional resources in terms of personnel and equipment. The increase in resources increases the program's cost. The middle section of the cost vs. schedule curve should be relatively flat, because in this region small incremental schedule changes should not increase cost dramatically. However, the slope of the cost-schedule curve increases as the program's schedule moves to either extreme on the curve.

The extreme left slope of the curve increases because larger amounts of personnel and equipment would be required to achieve the same incremental schedule increase that required less resources near the Point C. As the curve continues to the extreme left past

Point B schedule actually begins to increase again and the cost-schedule combinations achieved are inefficient. For example, Point A is inefficient because more resources are required to achieve the associated schedule than to achieve the same schedule outcome along arc B-C. This effect occurs because a minimum achievable program schedule exists. The addition of resources on the arc B-A makes management, coordination, and integration of resources difficult. These problems could actually cause inefficiencies that increase program schedule.

The cost-schedule curve, AD, in Figure 27 represents combinations of cost and schedule for a certain program quality level. However, other cost-schedule curves exist for different quality levels. On the curve Q_o, the movement to the right of Point C could be due to technical problems that increase schedule and cost. It is probable that the addition of resources used to solve this problem could result in a slightly higher program quality level. Program personnel could argue that the increase in cost and schedule is worthwhile because of the increase in program quality, Q_1, represented by Point F. However, this assumption is incorrect. As Figure 27 demonstrates, Point F is still inefficient on curve Q_1. If Q_1 is the initial quality objective, Point G is the least cost point and thus Point F to the right of Point G is inefficient. (Peck & Scherer, 1962) At this new performance level, the segment of curve Q_1 that achieves efficiency in development cost is the arc, H-G.

At this time, an explanation of "adjusting for quantity" and a discussion of the production cost-quantity curve is also necessary. Quantity changes can affect program cost in two ways; volume changes that directly affect cost growth, and volume changes that indirectly affect cost growth through secondary affects. Volume cost growth is approximately represented by the Quantity cost variance reported in SAR Section 13. "All

quantity changes shall be calculated using the baseline cost-quantity relationship in effect (DoD 7000.3, 1987, p.3-10)." The cost difference between the baseline cost-quantity relationship and the current cost-quantity relationship is allocated to the other cost variance categories (DoD 7000.3-G). This means that the quantity cost variance is based on the volume change between quantities.

Secondary effects such as spare changes or production rate changes are allocated to the other six cost variance categories. In this study, adjusting the program cost growth for quantity means adjusting the cost due to volume changes. The secondary cost effects are excluded from these quantity adjustments. The secondary effects are included in this research because the objective is to determine if a relationship exists between cost growth and schedule growth. One reason schedule growth occurs is because of the quantity change's secondary effect, such as production rate changes. These secondary effects should be analyzed but their measurement is beyond the scope of this thesis.

Figure 28 illustrates a hypothesized long-term relationship between production cost, quantity, and production rates. Recall that Figure 27 portrays the relationship between development cost and schedule. Figure 28 focuses only on production cost. This figure is derived theoretically and is not based on specific empirical analysis. The cost scale is exaggerated and not drawn to scale in order to demonstrate this hypothesized relationship. Figure 28 should help visualize the relationship between quantity change, production rate change, and schedule that is described on the previous page. As Figure 28 demonstrates, quantity and production rate affect the production cost. Along the arc A-D, when quantity increases, the schedule remains the same by adjusting the production rate. Therefore, if a program is operating at Point C and then moves to Point D, the production cost increases,

but the schedule remains the same. This situation occurs because, even though the quantity doubles, the production rate also doubles and thus 2*Q can be produced in the same amount of time. (Alchian, 1969, p.300)

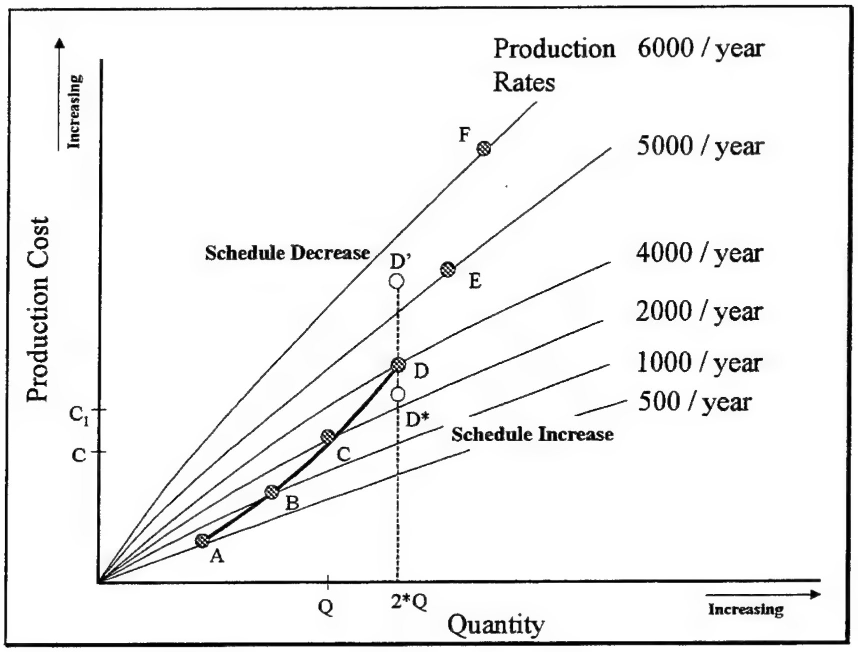

Figure 28. Theoretical Production Cost versus Quantity Curve

However, if the program moves from Point C to Point D* then the new quantity, 2*Q, takes longer to produce and schedule growth occurs. A portion of the cost growth, $C_1 - C$, is associated with this quantity change due to the change in volume, and some of the cost growth is due to the schedule growth resulting from the secondary effect, the production rate change. A program could also move from Point D to Point D', which reflects an increase in the production rate to reduce schedule when total quantity is not changed. In this situation, cost growth is due to schedule change.

A program could also move from Point D to Point D*, which is due to a decrease in the production rate and program schedule will increase. In this situation, production cost is reduced by the increase in a program's schedule and the associated increase in production

rate. However, as mentioned previously the cost scale is exaggerated and neither the cost increases nor decreases are as severe as depicted. Production cost is only part of the cost growth associated with schedule change.

Figure 28 represents the long-term planning view of how production cost, quantity, and production rate interact. Short-term changes in the production rate are not addressed by this relationship. Unplanned production rate or quantity changes that need to be addressed immediately to solve problems may induce a different relationship between these variables. It is also important to understand that program cost growth is a combination of development cost growth and production cost growth.

2. Cycle Time and Cost Correlation Research

In 1993, RAND Corporation conducted a cost growth study for the U.S. Air Force, which included all types of programs from all of the services. One aspect of this research was an analysis of the affect of schedule slip (schedule growth) on program cost growth. The researchers expected a strong correlation between these two program elements. However, the results demonstrated that a significant correlation between schedule slip and program cost growth does not exist. (Drezner, 1993)

In 1962, Peck and Scherer conducted an analysis of the correlation between development cost growth and schedule slippage. Their program sample consisted of ten DoD aircraft and missile programs. The following figure is a graph of their data. Peck and Scherer found that as program cycle time increases, the larger the development cost growth. The correlation coefficient in this study was .57, which is significant at the .10 level. (Peck & Scherer, 1962) This analysis shows that there is a relationship between development cost and schedule growth. However, it is important to understand that the cost growth factors in

both this thesis and the RAND study represent total cost growth adjusted for quantity. The Peck and Scherer analysis demonstrates that prior to production, a relationship exists between program cost and schedule growth. Therefore, two reasons could exist that explain these conflicting results. Either more homogeneous groups allow a more detailed analysis, or the addition of production costs cause the correlation effect to disappear.

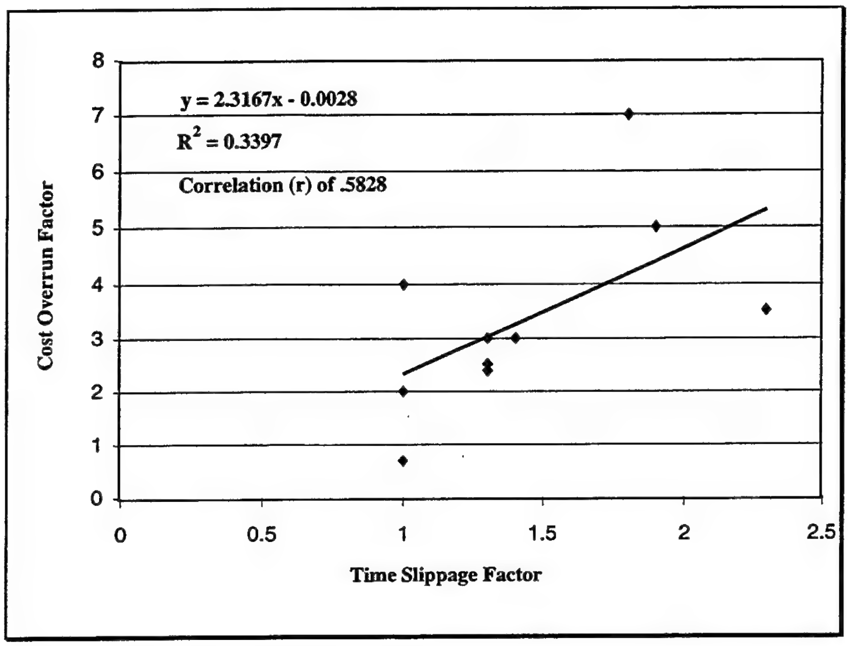

Figure 29. Peck and Scherer Schedule and Cost Variation Correlation

As the information in this section demonstrates, the theories and research concerning the relationship between cycle time and cost is contradictory. The RAND study seems to be the most relevant because of the large sample size, representation of adjusted total program cost, and because it is only 6 years old. However, the RAND study recommends further research in this area, specifically using more homogeneous groupings. More homogeneous groups, such as the sample in this research, allow for a more detailed study. Analysis at this level may identify relationships between schedule and cost that are masked at the macro level.

C. CYCLE TIME AND COST CORRELATION

This section presents an analysis of the correlation between program cost growth and cycle time growth. This analysis is divided into four parts. The first three parts of this section present the results of three simple regressions between cost growth factors and schedule growth factors (SGF) also referred to as cycle time growth. These results are presented in descending order of magnitude. First, an analysis is conducted to determine if cycle time growth affects unadjusted cost growth (TCGF). Then a more refined analysis is needed to assess whether cycle time growth affects quantity adjusted cost growth (TCGFA). The last single regression is still more refined and determines if cycle time growth affects schedule induced cost growth (STCGF). A null hypothesis is made, consistent with the conclusions of the RAND study, that cycle time growth does not affect cost growth.

H_o = Cycle time growth does not affect cost growth

H_1 = Cycle time growth affects cost growth

If H_o is rejected and H_1 is accepted, other assumptions are explored as follows:

TCGFA has a larger "r" than TCGF

STCGF has a larger "r" than TCGFA

The following rationale determines these assumptions. TCGF includes cost growth for all seven variance categories that affect cost growth. This includes quantity change, which is the largest cost growth driver after inflation (Hough, 1992). When using TCGF, cycle time is one of the seven variance factors, so if there is a correlation between cost growth and cycle time growth, the "r" value should be the smallest with TCGF. The correlation between TCGFA and cycle time should be the next largest because the cost growth is adjusted for quantity. Adjusting for quantity should more clearly demonstrate the

relationship between cycle time growth and the other six cost variance categories. The relationship between STCGF and cycle time growth should have the largest correlation. This seems obvious because STCGF is schedule induced cost growth as reported in the SAR Cost Variance Section. This explanation is shown graphically in the following figure.

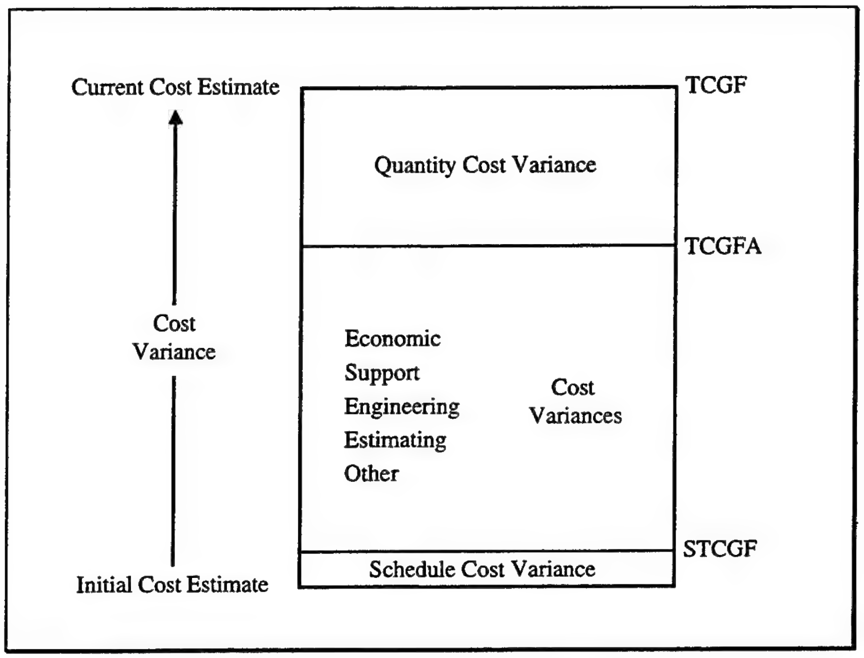

Figure 30. Explanation of Cost Growth Factors

The last part of this section presents the results of a multiple regression analysis between TCGFA and three other variables. These variables are initial program cost estimate, initial program schedule, and final program schedule.

1. Regression Analysis with TCGF

Figure 31 shows the relationship between TCGF and schedule growth factor. The regression analysis results in a coefficient of correlation (r) of 0.4978, which is significant at the .05 level. Thus, H_o is rejected and the alternate hypothesis is accepted. This demonstrates that a relationship exists between TCGF and schedule growth factor that is significant at the .05 level. In this analysis, one data point is an outlyer and this point is

removed from the analysis. The outlyer data is from the Bradley program. As explained in Appendix D, this program includes large cost adjustments in an effort to ensure only Bradley program costs are included in the cost growth factor. As Table 8 on page 101 shows, there is a large variance between the Bradley cost growth factors calculated by IDA, RAND, and in this research. Due to these factors, this program data is removed from this regression analysis.

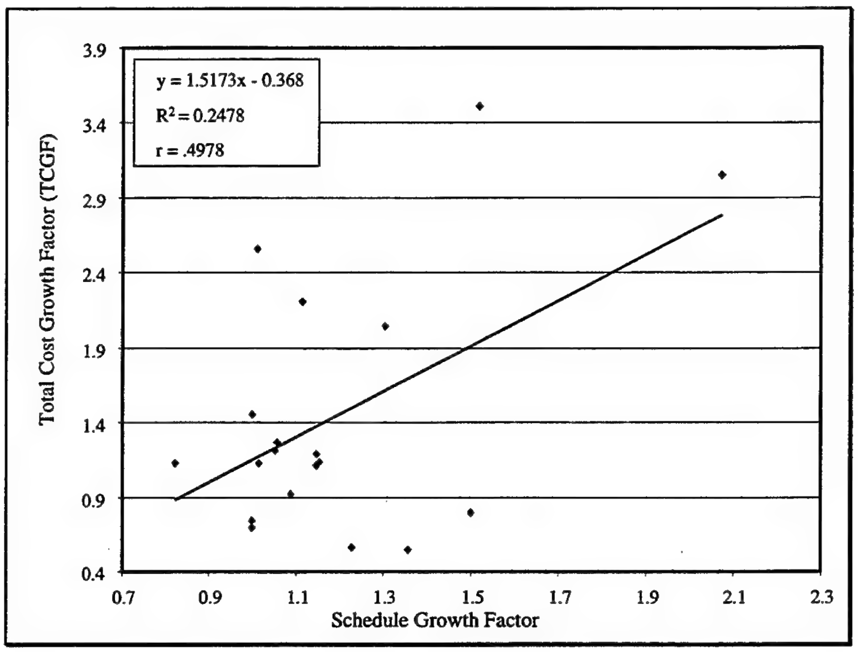

Figure 31: Correlation of TCGF to Schedule Growth Factor

2. Regression Analysis with TCGFA

Figure 32 presents the results of the regression analysis between TCGFA and schedule growth factor. As in the previous regression analysis, the Bradley program is also removed from this analysis to maintain consistency. This regression results in a “r” of 0.7539, which is significant at the .01 level. H_o is rejected and H_1 is accepted. This means that a significant relationship exists between TCGFA and the schedule growth factor. Since the “r” value is positive, as schedule growth increases, the program’s cost growth increases.

A regression analysis including the Bradley program data is presented in Appendix C. Even with the outlyer program, the "r" value is 0.4232, which is significant at the .10 level.

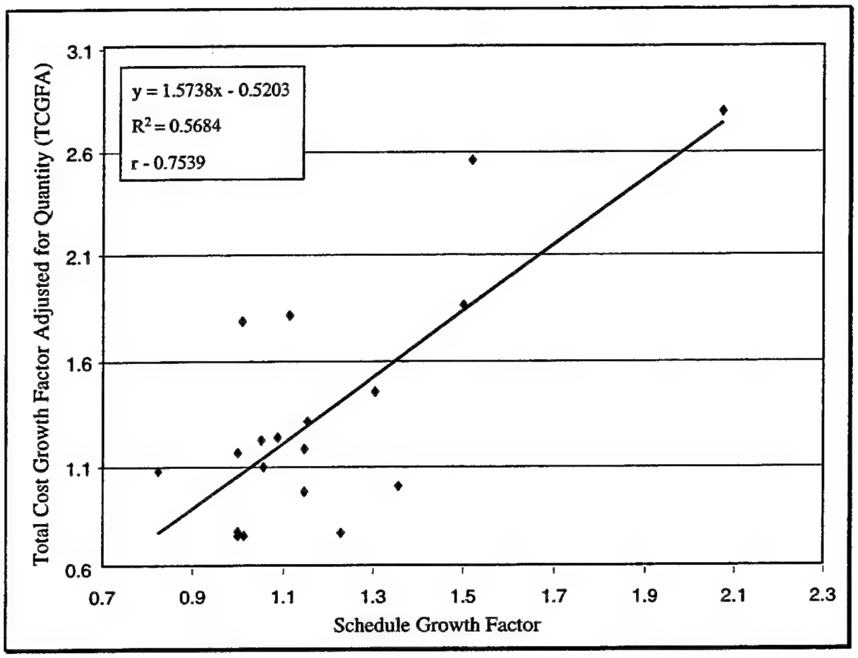

Figure 32: Correlation of TCGFA to Schedule Growth Factor

Since H_0 is rejected, the comparison of the strength of the association, "r" can be addressed. In this case, the first assumption is correct because the TCGFA "r" is larger than the TCGF "r". This means that the relationship between cost growth and schedule growth is more significant when the cost growth is adjusted for quantity. This result makes sense and is expected.

3. Regression Analysis with STCGF

Figure 33 presents the results of the regression analysis between STCGF and the schedule growth factors. As with the two previous regression analyses, the outlyer Bradley program is removed from the STCGF regression analysis. In this analysis, the STCGF "r" value is 0.3782, which is lower than both of the previous regression analyses. This analysis

demonstrates that the relationship between STCGF and SGF is not significant at the .10 level. This result means that there is a higher correlation between TCGFA and schedule growth factor than between the STCGF and schedule growth factor. This result is unexpected due to the explanations presented previously in this chapter. The STCGF variable is adjusted to include only cost growth due to schedule changes. For this reason, one would expect STCGF should have the highest correlation with the schedule growth factor.

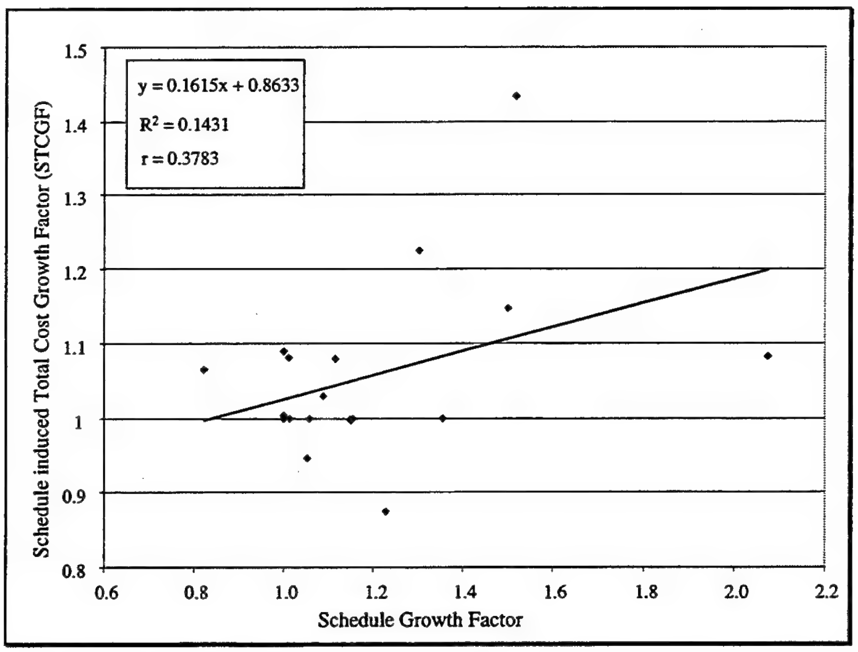

Figure 33: Correlation of STCGF to Schedule Growth Factor

A plausible explanation for the results of this regression analysis is that some of the cost variance due to schedule growth is attributed to one of the other five cost variance categories. If this situation occurs, then the schedule induced cost growth factor (STCGF) does not represent all of the cost growth due to schedule growth. Thus, the relationship between STCGF and the schedule growth factor is not as significant as it would be if the schedule variance category represented all of the schedule induced cost growth.

4. Multiple Regression Analysis

The last part of Section C provides the results of a multi-regression analysis of the TCGFA. Regression analysis is conducted with three dependent variables in log log form (Ln); TCGF, TCGFA, AND STCGF. The independent variables are the Ln (initial cost estimate in 1998 constant dollars), Ln (initial schedule estimate in months), and the Ln (current schedule estimate in months). The log log form is a more complex method of presenting this data than the straight linear model. However, the log log form is used because this form has better statistical properties and identifies the effects of initial cost and initial schedule on TCGFA. The log log form also enables the multi-regression equation to be transformed in order to arrive at an equation in terms of TCGFA and schedule growth factor. The multiple regression analysis indicates that the best model uses Ln TCGFA as the dependent variable. This is consistent with the results obtained in the simple regression analysis.

The multi-regression analysis that is presented in this section uses the following variables:

- Dependent Variable: Ln (Current (final program) cost adjusted for quantity in 1998 constant year dollars) ($Cost_{AQ}$)
- Independent Variables:
  - Ln (Initial Program Cost in 1998 constant year dollars) ($Cost_{IN}$)
  - Ln (Initial Schedule in months) ($Sched_{IN}$)
  - Ln (Current Schedule in months) ($Sched_{CUR}$)

As explained in Chapter III, each cost dollar amount is in constant program base-year dollars; however, the base-year differs between programs. In order to conduct this

regression analysis, the cost dollar amounts need to be in the same base-year. Total Obligation Authority (TOA) 1999 DoD deflators are used to adjust the various base-years to the 1998 base-year used in this research.

The results of the multiple regression are shown below in the regression equation.

$$\mathrm{Ln}(\mathrm{Cost}_{AQ}) = -2.6 + 1.15*\mathrm{Ln}(\mathrm{Cost}_{IN}) - 1.11*(\mathrm{Sched}_{IN}) + 1.41*\mathrm{Ln}(\mathrm{Sched}_{CUR})$$

Each of the regression coefficients is significant to the .01 level. This equation demonstrates that a 1% change in the initial cost leads to a 1.15% change in the final cost adjusted for quantity when the other variables are held constant. This means that higher initial cost programs could have greater cost growth. This regression equation also shows that a 1% change in initial schedule results in a –1.1% change in the final cost adjusted for quantity. This means that a longer initial program length leads to a lower final cost. This makes sense from the long-term production graph that has already been discussed. If you plan for a longer program, then the program final cost would be less than when based on an overly optimistic schedule. The same equation also demonstrates that a 1% change in final schedule results in a 1.4% change in the final program cost. Since all other variables are held constant, the 1% change in final schedule is equal to a 1% change in schedule growth. This result makes sense due to the results of the simple correlation analysis that shows cost growth is affected by schedule growth.

The next step in this analysis is to transform the regression equation into an equation. This form is desired because now the equation is in terms of TCGFA and SGF, which are the norms for this type of research. The simple regression analysis is also conducted using these factors.

$$\mathrm{Ln}(\mathrm{TCGFA}) = -2.6 + .15*\mathrm{Ln}(\mathrm{Cost}_{IN}) + 1.41*\mathrm{Ln}(\mathrm{SGF}) + .3*\mathrm{Ln}(\mathrm{Sched}_{IN})$$

The above equation is analyzed using regression analysis to determine the significance of the coefficients and to verify that the same coefficients are determined. The results of the regression analysis show that the initial cost is significant to the .06 level and that the SGF is significant to the .01 level. The effect of the initial schedule is not significant in this equation. Since the initial schedule is not significant in this case, the regression equation is reestimated without the initial schedule variable. The results of this new multiple regression analysis show that SGF is significant to the .01 level and initial program cost is significant to the .05 level. The following regression equation shows the multiple regression results.

$$Ln(TCGFA) = -1.2 + .165*Ln(Cost_{IN}) + 1.29*Ln(SGF)$$

This equation shows that if the initial program cost changes by 1% then the TCGFA changes by a factor of .165% and that if the SGF changes by 1% then the TCGFA changes by 1.29%. The antilog of this equation is also available to provide the following equation in terms of TCGFA.

$$TCGFA = e^{-1.24} * Cost_{IN}^{.165} * SGF^{1.29}$$

As indicated holding the initial cost constant, this equation shows that a 1% increase in the schedule causes TCGFA to increase by a factor of 1.29. This is considerably less than the factor of 4 that was presented by Deputy Under Secretary of Defense (Advanced Technology) in a briefing on cycle time reduction in 1998 (Eash, 1998).

The limitations of this model must be understood. This model is based on a multiple regression analysis of only 19 data points. The Bradley program is deleted as an outlyer as described earlier in this chapter. This model also initially only includes three independent variables and results in an equation of only two independent variables. There are numerous other factors that could affect both the cost growth and the schedule growth that are not

explored in this analysis of the relationship between cost and schedule. This log normal model also assumes that the full effect of the other causes of cost growth are either captured through the effect of these factors on schedule growth or are unrelated to either the initial cost levels or to schedule growth. A more complete model would need to account for all of these factors.

This simple model is derived to better understand the simple correlation results. The simple correlation results demonstrate that a relationship exists between schedule growth and cost growth. This simple model provides a limited understanding of the magnitude of that relationship, and may have only limited value in predicting how an actual schedule change affects a program's actual final cost. An explanatory model would need to be of a high-tier order and include a detailed understanding of the numerous variables that affect program growth, of which only one is schedule growth. A particularly important variable that must be included in any cost prediction model is the performance level. More discussion of this type of predictor model is discussed in the recommendations section of Chapter VI.

D. SUMMARY

This chapter provides an analysis of the effects of program schedule growth on program cost growth. The postulated theories and research conclusion on this topic do not always agree. Logic and common sense provide a theory that program cost should increase as program schedule increases as depicted in Figure 27 on page 84. However, research conducted by RAND and IDA does not find a significant correlation between these two important elements of an acquisition program. However, the research conducted by RAND and IDA incorporates all categories of acquisition programs procured by all four services.

This type of research provides a macro-view of cost trends and thus some cost trends may be masked at this level of analysis. (Drezner, 1993)

The Peck and Scherer research in 1962 and the results of this research support the hypothesis that some cost trends are masked at the macro-level. The Peck and Scherer research includes 10 aircraft and tactical missile programs. This research includes 20 Army programs that incorporate the entire acquisition cycle from MSI to IOC. Not all of the programs in this research have reached IOC; however, each program intends to incorporate MSI to IOC in their acquisition strategy. The research on the affects of schedule growth on cost growth, using homogeneous groups, demonstrates that an association exists between schedule growth and cost growth. The Peck and Scherer research shows the relationship between cost growth adjusted for quantity and schedule growth is significant at the .10 level, and this research shows the relationship is significant at the .01 level.

One result of the simple regression analysis conducted in this chapter is unexpected and not easily explained. This result is that STCGF has less correlation with schedule growth than TCGFA. A hypothesized explanation is that some of the cost variance that should be allocated to schedule cost variance is misallocated to one of the other five cost variance categories. This explanation makes sense for the following reasons. TCGFA includes all cost growth except cost growth due to quantity, meaning volume cost changes. This research demonstrates that a relationship exists between TCGFA and SGF. Since STCGF represents only cost growth induced by schedule changes, this cost growth factor might be expected to have the highest correlation. Since TCGFA is highly correlated with schedule growth and STCGF represent schedule induced cost growth, which should have a higher correlation to schedule growth, a misallocation of cost variance is plausible.

The multiple regression analysis conducted with TCGFA in the log log model demonstrates that both initial cost and SGF are significantly related to cost growth. The initial cost is significant at the .05 level and SGF is significant at the .01 level. A simple model is derived between TCGFA and the independent variables of initial cost and SGF. This simple model provides a limited understanding of the magnitude of the relationship between TCGFA and SGF. However, this model should be used very cautiously when predicting how an actual schedule change affects a program's actual final cost. Further empirical work might be successful in developing a superior predictor model that would include all of the numerous variables that affect program growth, of which only one is schedule growth.

Table 8 presents a comparison of the cost growth factors calculated in this research as compared to the cost growth factors extracted from RAND and IDA studies. As shown, the majority of the cost growth factors are very similar. The cost growth factors in bold type represent factors calculated with different SAR year data and should have differences.

Table 8. Comparison of Cost Growth Factors

Program	TCGFA	IDA (TPCG)	RAND (DE)
Year	**1997**	**1993**	**1990**
AGM-114 HELLFIRE	1.458	1.44	1.47
LANCE	1.169	1.12	1.17
AH-64A	1.818	1.65	1.52
UH-60A	1.227	1.23	1.2
COPPERHEAD	1.861	2.12	1.65
M1 ABRAMS	1.792	1.4	1.52
BRADLEY	4.329	3.5	2.41
CH-47D	1.32	1.32	1.28
OH-58D	1.34	1.3	1.53
JAVELIN	**1.241**		**1.02**
AFTADS	**0.978**		**1.13**
PLS	**1.005**		**1.06**
LONGBOW HELLFIRE	**1.1**		**1.0**

This table is presented to add validity to the research results in this chapter. Even though slightly different methodologies are used to calculate the cost growth factors, the majority of the cost growth factors are very similar. The schedule data is not presented in this manner because the schedule data for this analysis is extracted from the CTAT database, which has been developed by the Under Secretary of Defense for Acquisition and Technology.

VI. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

This chapter provides a concise summary of the important aspects of this research. This document begins by laying the groundwork that must be understood, in order, to fully comprehend the results of the analysis. This groundwork includes providing information on the three important elements of the DoD Acquisition Process, and then presenting an argument for the importance of cycle time and cost research. Next, the cycle time and cost methodology are presented, which explains how the cycle time and cost variables are derived for the analyses in Chapters IV and V. The methodology also provides information on previous theories and research conducted on this topic.

The theories and research on how program schedule growth affects program cost growth do not always reach the same conclusions. Logic and common sense provide theories that program cost should increase as program schedule increases. Research conducted in 1962 found a correlation exists between program schedule growth and program cost growth. However, research conducted by RAND and IDA on acquisition programs, in the early 90s, does not identify a significant correlation between these two important elements. The research conducted by RAND and IDA incorporates all categories of acquisition programs procured by all four services. This type of research provides a macro-view of cost trends and thus certain cost trends may not be visible at this level of analysis. (Drezner, 1993) The RAND study recommends further research, using homogeneous program groups to determine if this type of research provides the same results as the DoD-wide analysis results.

The objectives of this research are to determine the magnitude of cycle time growth and cost growth for the selected Army programs. Once the cycle time and cost growth trends are determined separately, a correlation analysis is conducted to explore if a relationship exists between program cycle time growth and cost growth within a homogeneous group of Army programs. Analysis of a homogeneous group of programs may reveal schedule and cost relationships that are masked at the macro-level.

This chapter is divided into three sections; research conclusions, recommendation based on research findings, and suggested areas for further research. The conclusions and recommendations are intended to generate discussion on the need to further explore or expand this research.

B. CONCLUSIONS

This section discusses the conclusions drawn from the results of this research analysis. The conclusions are presented in three sections; changing acquisition environment, Army Program cycle time and cost growth, and cycle time and cost growth correlation.

1. Changing Acquisition Environment

The current DoD Acquisition Process must adapt to the new security and budgetary environment. The three factors changing the acquisition environment are the change in threat environment, a decreasing defense budget, and the need to modernize existing weapon systems. These circumstances require the DoD to field new systems quickly and upgrade existing equipment within the constraints of a significantly reduced defense budget.

The current DoD Acquisition Process is structured to solve technical problems based on a stable, known threat. However, the future battlefield has become fluid and

complex, focusing on peacekeeping operations like Bosnia, Haiti, Somalia, and Kosovo. Today's United States military forces must be able to react to various threats by fielding systems in a timely manner, before the threat shifts or changes.

To further compound the current situation of a changing threat and reduced budget, the equipment and systems currently used by DoD soldiers are nearing the end of their expected lifetime. These systems will soon need to be replaced with upgraded systems incorporating the newest technology. The military services must be able to develop, produce, and field these upgraded or new systems within the constraints of the reduced defense budget and at an accelerated cycle time required to adapt to the ever-changing threat environment.

2. Army Program Cycle Time and Cost Growth

This research demonstrates that Army programs are experiencing positive cycle time growth. The overall average growth for full cycle programs is 19.6 months as compared to the average modification program growth of 4.1 months. Phase II of the Acquisition Process, EMD, demonstrates the highest average growth in both of the groups. The full cycle group's Phase II average growth is 14.3 months and the modification group's average growth is 9.2 months. The PGM commodity has the greatest average growth (51 months) in the full cycle group and the C3I commodity has the greatest average growth (9 months) in the modification group.

All of the full cycle commodities have a greater average program length than their modification commodity counterparts. The full cycle program average length is 137.2 months or 11.4 years. The modification program average length is 69.6 months or 5.8 years. Within the full cycle group, the PGM commodity has the greatest average length (166

months) and the Helicopter commodity has the greatest average length (84 months) in the modification group.

Correlation analysis is conducted between program schedule growth and initial program length estimate. There is no demonstrated correlation between these factors in the full cycle programs; however, a strong correlation, $r = -0.661$, exists between these factors for the modification programs. This is a significant result that demonstrates as the initial length of modification programs increases, the amount of schedule growth decreases. Further research should be conducted to determine reasons why the modification programs demonstrate a strong correlation and the full cycle programs show no significant correlation.

This research reveals that Army programs are experiencing positive program cost growth. Due to combined cost data in the SARs for modification programs, this research is only able to determine the cost growth for the full cycle programs. The Army program average cost growth, adjusted for quantity change, is 49.9%. This number compares very closely with a DoD-wide average cost growth, adjusted for quantity of 47% reported by IDA in 1992. The 49.9% cost growth includes a development cost growth of 38.2%, and a procurement cost growth of 52.1%.

Three of the five commodity groups have cost growth of almost 100%, with the Vehicle commodity the greatest at 105.2%. The majority of the Vehicle and Helicopter commodity average cost growth, adjusted for quantity, is due to the Bradley program and the RAH-66 program, respectively. The Bradley program has an adjusted cost growth of 329%, and the RAH-66 program has an adjusted cost growth of 179%. The cost growth due to schedule changes as reported in the SAR Section 13 variance categories is also analyzed. The cost growth induced by schedule is only 14.3% of the overall cost growth adjusted for

quantity, which is a relatively small part of the overall adjusted cost growth. This percentage becomes even smaller when the cost growth is not adjusted for quantity.

Correlation analysis is conducted between the cost growth factors and other cost related program issues. The relationship or association is analyzed between TCGFA and STCGF, and the following program cost related issues:

- Initial Cost Estimate
- Year of Program Start

None of these simple correlation analyses demonstrate any significant relationship between the examined variables.

3. Correlation Between Cycle Time and Cost Growth

The correlation analysis between cycle time and cost growth demonstrates that a significant association exists between these two program factors. Using a homogeneous group, Army programs that incorporated all of the acquisition milestones, this research demonstrates a significant relationship between schedule growth and cost growth. Based on the results of this research, the relationship between cost growth adjusted for quantity and schedule growth is significant at the .01 level. This result means that if a program's schedule increases then it is very likely that the program's cost also increases.

A multiple regression analysis is used to further explore the relationship between schedule growth and cost growth. Since TCGFA demonstrated the highest correlation with SGF in the simple regression, TCGFA is used as the base-case dependent variable in the multiple regression analysis. The independent variables are the Ln (initial cost estimate in 1998 constant dollars), Ln (initial schedule estimate in months), and the Ln (current schedule estimate in months). The log log form is used both because this form yields a

model with better statistical properties and identifies the effects of initial cost, initial schedule, and current schedule on TCGFA. The log log form also enables the multiple regression equation to be represented with an equation that includes both TCGFA and schedule growth factor (SGF). The equation resulting from the multiple regression analysis is presented below:

$$Ln(TCGFA) = -1.2 + .165*Ln(Cost_{IN}) + 1.29*Ln(SGF)$$

This equation demonstrates that if the initial program cost changes by 1% then the TCGFA changes by a factor of .165%, and that if the SGF changes by 1% then the TCGFA changes by 1.29%. The coefficients in the regression equation are significant at the .05 level for initial cost and at the .01 level for SGF.

As explained in Chapter V, this simple model has limitations that must be understood. The model is based on a multiple regression analysis of only 19 data points. This log log model also assumes that schedule growth occurs independently of other causes of cost growth, which in the real world does not occur. This model is derived to better understand the results of the simple correlation, and to provide an initial understanding of the magnitude of the cost-schedule relationship. However, it must be used very carefully to predict how an actual schedule change affects a program's actual final cost. A better explanatory model should include all of the relevant variables that affect program cost growth.

C. RECOMMENDATIONS

This research demonstrates that a possible relationship exists between cycle time growth and cost growth. Further research must be conducted to verify these results and then continue to explore the effects of schedule growth on cost growth.

1. Cost, Schedule, and Performance Relational Database

The first recommendation is to develop a relational database that incorporates the three important factors associated with an acquisition program; cost, schedule, and performance. This type of database would permit the analysis of the relationship among these program factors. Understanding the interaction and relationship between these three program factors, increases the accuracy of the initial program's cost and schedule estimates based on a desired level of performance. Funding instability is a contributing factor to program instability, which can lead to cost and schedule growth. Some of the funding instability occurs because of inaccurate initial cost estimates. Increasing acquisition program stability could be a secondary effect of accurate initial cost and schedule estimates.

One important component of the required work to develop this type of database already exists in the form of the CTAT. This tool could be initially merged with a cost database and then the performance data could be added when it becomes available. This type of research is currently being conducted at OSD Program Analysis and Evaluation (PA&E). The PA&E personnel are in the initial stages of developing a program cost database for MSII to MSIII. Instead of using baseline estimates (PE, DE, and PdE), this database will be based on cost estimates at the various Defense Acquisition Process Milestones. Future PA&E plans are to incorporate the program schedule information. At present there are no plans to incorporate the performance data. (Pannullo, 1999)

2. Incorporate Software Cost in the SAR

The second recommendation is that the next SAR update should include a software cost variance category in SAR Section 13. The DoD weapons systems reliance on software continues to grow and software has become and increasingly evident problem in program

management. "When a major procurement programs turn into a fiasco, when costs soar, deliveries fall behind schedule, and performance is compromised, more times than not the problem can be traced to one high-risk component—the software (Software Technology Support Center, 1996, p.1-5)". In June 1992, an Air Force Software Process Action Team reported that one of the three top problem areas in software program development is the program acquisition baseline. Usually the schedule estimate is understated. (Software Technology Support Center, 1996) Incorporating program software data into the SARs is a viable method of tracking the effects of software development across all acquisition programs.

3. Reform Initiatives

Based on the results of this research, future acquisition reform initiatives should target cycle time reduction and cost reduction separately. This course of action is recommended because only 14.3% of adjusted cost growth, as reported in the SAR, is attributed to schedule. Acquisition reform initiatives should address cycle time reduction due to the changing threat environment. Cost reduction should be addressed because of the austere fiscal environment that is exacerbated by the increasing necessity to modernize the military's existing equipment. This research demonstrates that reform initiatives that reduce cycle time will provide the added benefit of a small decrease in cost growth.

However, further research needs to be conducted on the accuracy of the allocation of schedule induced cost growth to the schedule cost variance. If further research demonstrates that the schedule induced cost growth is misallocated and that the percentage of cost growth due to schedule is higher, then acquisition reform initiatives should have a different

objective. In this case, reform initiatives should target cycle time reduction in order to field systems quickly, with a secondary objective of significantly reducing the program cost.

D. AREAS FOR FURTHER RESEARCH

- Theoretical analysis on combining the hypothesized program development cost curve with the hypothesized production cost curve. Combining these two curves results in a total cost curve for the program.
- This research analyzes the affect of program schedule growth on program cost growth. Further research should be conducted on the relationship between development schedule growth and development cost growth. This type of analysis would also provide additional insight on the hypothesized development cost curve.
- Further research could be conducted on the relationship between production schedule growth and production cost growth. This type of analysis would also provide additional insight on the hypothesized production cost curve.
- This research demonstrates that a schedule and cost growth relationship exists for one homogeneous program group. This result should be explored with other homogeneous program groups. Research should be conducted on Air Force programs, Navy programs, aircraft programs, vehicle programs, etc…
- Compare and contrast the current DoD Acquisition Process to the principles incorporated in lean manufacturing to determine whether the principles are applicable to the DoD and what would be their impact on program cost and schedule.
- Conduct an analysis on software induced program schedule and cost growth. What is the magnitude of this software induced program growth? How has this affect changed over time? Which of the current SAR cost variance categories is the software affect

allocated? Should software induced cost growth be a cost variance category in the SAR?

- Compare the development of the Boeing 777 to the Army RAH-66 program. Compare and contrast the differences in the management processes. What lessons learned from the Boeing development are applicable to the RAH-66 program? What lessons learned are generally applicable to all acquisition programs?
- Use the analysis in this research and focus on the schedule cost growth paradox. Why does TCGFA have a higher correlation to schedule growth than the STCGF? One can hypothesize that some schedule induced cost growth is misallocated to other cost variance categories.
- Use the analysis in this research and focus on the reasons for schedule and cost growth. What are the significant reasons that account for schedule and cost growth? Do current acquisition reform initiatives address the reasons for this growth?
- Research the affects of acquisition reform initiatives since 1960. As this study demonstrates, there is little correlation between year of program start and cycle time growth and cost growth. This means that the magnitude of program cycle time and cost growth is not being reduced. Explore the acquisition reform initiatives, over this time period, to determine why program cost growth and cycle time growth is not being reduced. Also, compare and contrast any earlier reform initiatives with the current acquisition reform initiatives. Will the current set of acquisition reform initiatives have an impact on reducing cycle time and cost growth?
- This research explored the relationship between schedule growth and cost growth adjusted for quantity, which included the secondary effects of quantity change on

schedule. Building on these results, further research could explore the impact of performance and quantity change's secondary affects on schedule induced cost growth. The following model could be used as a start point.

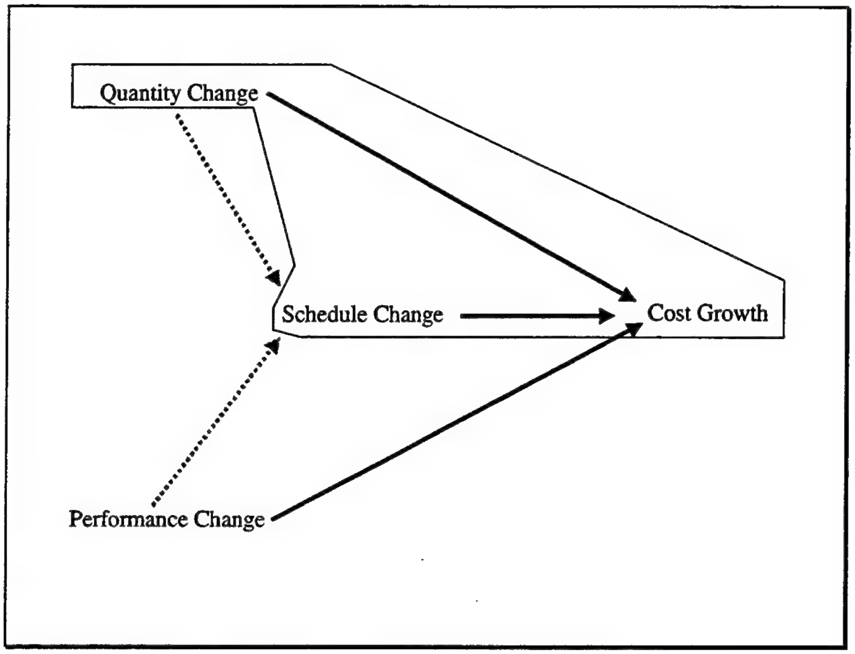

Figure 34. Factors that Affect Cost Growth

The boxed line indicates the scope of the research conducted in this analysis. This thesis adjusts cost growth to account for the affects of quantity volume change; however, this research does not directly estimate the affects of quantity volume change. Research should also explore the primary effects (black lines) of quantity change and performance change on cost growth. Then the secondary affects on schedule induced cost growth (dashed lines) and the resulting impact on cost growth could be determined.

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ACRONYMS

ACAT - Acquisition Category

ADM - Acquisition Defense Memorandum

APB - Acquisition Program Baseline

ARSSG - Acquisition Reform Senior Steering Group

ASD(C) - Assistant Secretary of Defense, Comptroller

ASD (C3I) - Assistant Secretary of Defense (C3I)

BES - Budget Estimate Submissions

C3I - Command, Control, Communication & Intelligence

CAE – Component Acquisition Executive

CE - Concept Exploration

CIO - Chief Information Officer

CJCS - Chairman of the Joint Chiefs of Staff

CTAT - Cycle Time Analysis Tool

DAB - Defense Acquisition Board

DCGF - Development Cost Growth Factor

DCGFA - Development Cost Growth Factor Adjusted

DE - Development Estimate

DEV - Development

DoD - Department of Defense

DPG - Defense Planing Guidance

DSAC - Defense System Affordability Council

DT - Developmental Testing

EMD - Engineering & Manufacturing Development

FASA - Federal Acquisition Streamlining ACT

FSD - Full Scale Development

FYDP - Future Years Defense Program

GAO - General Accounting Office

IDA - Institute for Defense Analysis

IOC - Initial Operational Capability

JCS - Joint Chiefs of Staff

LCC - Life Cycle Cost

LRIP - Low Rate Initial Production

MAA - Mission Area Assessment

MAIS - Major Automated Information Systems

MDA - Milestone Decision Authority

MDAP - Major Defense Acquisition Program

MNS - Mission Need Statement

MS - Milestone

NCA - National Command Authority

NMS - National Military Strategy

NPR - National Performance Review

NSC - National Security Council

NSS - National Security Strategy

O & M - Operations and Maintenance

OMB - Office of Management and Budget

ORD - Operational Requirements Document

OSD - Office of the Secretary of Defense

OT - Operational Testing

PA&E - Program Analysis and Evaluation

PCGF - Procurement Cost Growth Factor

PCGFA - Procurement Cost Growth Factor Adjusted

PdE - Production Estimate

PDRR - Program Definition & Risk Reduction

PE - Planning Estimate

PGM - Precision Guided Munitions

PM - Program Manager

PMO - Program Management Office

POM - Program Objectives Memoranda

PPBS - Planning, Programming, and Budgeting System

PROC - Procurement

QDR - Quadrennial Defense Review

RDT&E - Research, Development, Test & Evaluation

RMA - Revolution in Military Affairs

SAR - Selected Acquisition Reports

SDCGF - Schedule induced Development Cost Growth Factor

SPCGF - Schedule induced Procurement Cost Growth Factor

STCGF - Schedule induced Total Cost Growth Factor

TCGF - Total Cost Growth Factor

TCGFA - Total Cost Growth Factor Adjusted

TEMP - Test & Evaluation Master Plan

TOA - Total Obligation Authority

USD(A&T) - Under Secretary of Defense (Acquisition and Technology)

APPENDIX A: CYCLE TIME DATA TABLES

This appendix provides the cycle time data in table format. The first two tables in this appendix represent the cycle time data condensed into summary tables for full cycle programs and modification programs. These are the tables used to generate the cycle time figures in Chapter IV. The tables from page 122 to 131 represent the raw cycle time data in date format as extracted from the CTAT database. The tables from page 132 to 141 represent the same raw cycle time data; however, the data has been converted to months. These tables are also extracted from the CTAT database.

Table A1. Full Cycle Program Summary Cycle Time Data

Program Name	Growth MS I - MS II	Org Est	% Growth	Growth MS II- MS III	Org Est	% Growth	Growth MS III - IOC	Org Est	% Growth	Growth Pro Srt - IOC	Org Est	% Growth	Program Length	# of Programs
TACTICAL MISSILE														
AAWS-M (JAVALIN)	0	37	0.00%	35	60	58.33%	-25	18	-138.89%	10	115	8.70%	125	5
AGM-114 (HELLFIRE)	0	38	0.00%	4	69	5.80%	34	18	188.89%	38	125	30.40%	163	
LANCE	0	59	0.00%	5	32	15.63%	-5	22	-22.73%	0	113	0.00%	113	
LONGBOW HELLFIRE	0	64	0.00%	10	72	13.89%	5	4	125.00%	15	140	10.71%	155	
ATACMS/APAM	0	94	0.00%	14	43	32.56%	-12	9	-133.33%	2	146	1.37%	148	
TOTAL	0	292	0.00%	68	276	126%	-3	71	18.94%	65	639	51.18%	704	
AVERAGE	0	58.4	0.00%	13.6	55.2	25%	-0.6	14.2	3.79%	13	127.8	10.24%	140.8	
C3I														
AFATDS	2	62	3.23%	18	57	31.58%	4	9	44.44%	24	128	18.75%	152	5
AN/TTC-39	0	22	0.00%	-8	83	-9.64%	32	0	3200.00%	24	105	22.86%	129	
CHANNEL ANTI-JAM	0	5	0.00%	-15	45	-33.33%	15	22	68.18%	0	72	0.00%	72	
LONGBOW AH-64	5	59	8.47%	12	46	26.09%	12	24	50.00%	29	129	22.48%	158	
SMART-T	0	15	0.00%	1	77	1.30%	-1	14	-7.14%	0	106	0.00%	106	
TOTAL	7	163	11.70%	8	308	15.99%	62	69	3355%	77	540	64.09%	617	
AVERAGE	1.4	32.6	2.34%	1.6	61.6	3.20%	12.4	13.8	671%	15.4	108	12.82%	123.4	
HELICOPTERS														
AH-64	1	50	2.00%	16	47	34.04%	0	52	0.00%	17	149	11.41%	166	4
COMANCHE 1	43	32	134.38%	-9	59	-15.25%	0	1	0.00%	34	92	36.96%	N/A	
COMANCHE 2	48	112	42.86%	-4	61	-6.56%	3	2	150.00%	47	175	26.86%	222	
UH-60	0	14	0.00%	30	56	53.57%	-25	26	-96.15%	5	96	5.21%	101	
TOTAL	92	208	179.2%	33	223	65.80%	-22	81	53.85%	103	512	80.43%	489	
AVERAGE	23	52	44.81%	8.25	55.75	16.45%	-5.5	20.25	13.46%	25.75	128	20.11%	163	
PGM														
ATACMS-BAT	0	75	0.00%	53	67	79.10%	3	13	23.08%	56	155	36.13%	211	3
COPPERHEAD	0	21	0.00%	49	53	92.45%	-12	0	-1200.00%	37	74	50.00%	111	
SADARM	0	40	0.00%	54	75	72.00%	6	1	600.00%	60	116	51.72%	176	
TOTAL	0	136	0.00%	156	195	243.56%	-3	14	-577%	153	345	137.85%	498	
AVERAGE	0	45.33	0.00%	52	65	81.19%	-1.00	4.67	-192%	51	115	45.95%	166	
VEHICLES														
CRUSADER	-5	76	-6.58%	-5	66	-7.58%	-18	16	-112.50%	-28	158	-17.72%	130	4
MI ABRAMS	0	48	0.00%	8	51	15.69%	-7	-2	-350.00%	1	97	1.03%	98	
MICV BRADLEY	0	7	0.00%	0	86	0.00%	15	30	50.00%	15	123	12.20%	138	
PLS (FHTV)	0	12	0.00%	32	23	139.13%	-7	21	-33.33%	25	56	44.64%	81	
TOTAL	-5	143	-6.58%	35	226	147.24%	-17	65	-445.83%	13	434	40.15%	447	
AVERAGE	-1.25	35.75	-1.64%	8.75	56.5	36.81%	-4.25	16.25	-111.46%	3.25	108.5	10.04%	111.75	
OVERALL TOTAL	**94**	**942**	**184%**	**300**	**1228**	**599%**	**17**	**300**	**2406%**	**411**	**2470**	**374%**	**2881**	
OVERALL AVERAGE	**4.48**	**44.86**	**8.78%**	**14.29**	**58.48**	**28.51%**	**0.81**	**14.29**	**114.55%**	**19.57**	**117.62**	**17.80%**	**137.190476**	
NUM OF PROGRAMS	21													

Table A2. Modification Program Summary Cycle Time Data

Program Name	Growth MS I - MS II	Org Est	% Growth	Growth MS II - MS III	Org Est	% Growth	Growth MS III - IOC	Org Est	% Growth	Growth Pro Srt - IOC	Org Est	% Growth	Protgram Length	# of Programs	First SAR Year
TACTICAL MISSILE															
AGM-114 HELLFIRE	N/A	N/A	N/A	0	46	0.00%	0	19	0.00%	0	65	0.00%	65	3	1992
ATACMS/APAM BL 1A	N/A	N/A	N/A	14	35	40.00%	-14	13	-107.69%	0	48	0.00%	48		1983
STINGER RMP	N/A	N/A	N/A	1	41	2.44%	11	9	122.22%	12	50	24.00%	62		1993
TOTAL	N/A	N/A	N/A	15	122	42.44%	-3	41	14.53%	12	163	24.00%	175		
AVERAGE	N/A	N/A	N/A	5.00	40.67	14.15%	-1.00	13.67	4.84%	4.00	54.33	8.00%	58.33		
C3I															
ASAS BL II	N/A	N/A	N/A	19	58	32.76%	-51	57	-89.47%	-32	115	-27.83%	83	2	1991
MCS BL III	N/A	N/A	N/A	60	8	750.00%	-10	12	-83.33%	50	20	250.00%	70		1991
TOTAL	N/A	N/A	N/A	79	66	782.76%	-61	69	-172.81%	18	135	222.17%	153		
AVERAGE	N/A	N/A	N/A	39.5	33	391.38%	-30.5	34.5	-86.40%	9	67.5	111.09%	76.5		
HELICOPTERS															
CH-47D	N/A	N/A	N/A	1	59	1.69%	-1	41	-2.44%	0	100	0.00%	100	2	1978
KIOWA WARRIOR	N/A	N/A	N/A	4	45	8.89%	6	13	46.15%	10	58	17.24%	68		1982
TOTAL	N/A	N/A	N/A	5	104	10.58%	5	54	43.71%	10	158	17.24%	168		
AVERAGE	N/A	N/A	N/A	2.5	52	5.29%	2.5	27	21.86%	5	79	8.62%	84		
PGM															
ATACMS BAT P3I	7	53	13.2%	-3	47	-6.38%	-8	12	-66.67%	-4	112	-3.57%	108	3	1994
ATACMS BAT BLOCK IIA	N/A	N/A	N/A	10	47	21.28%	-12	15	-80.00%	-2	62	-3.23%	60		1994
ATACMS BAT BLOCK II	N/A	N/A	N/A	8	64	12.50%	4	0	400.00%	12	64	18.75%	76		1994
TOTAL	7	53	13.21%	15	158	27.39%	-16	27	253.33%	6	238	11.95%	244		
AVERAGE	7	53	13.21%	5	52.67	9.13%	-5.33	9	84.44%	2	79.33	3.98%	81.33		
VEHICLES															
BFVS/A3 UPGRADE	N/A	N/A	N/A	1	69	1.45%	3	6	50.00%	4	75	5.33%	79	4	1993
M1A1	N/A	N/A	N/A	N/A	N/A	N/A	0	20	0.00%	0	20	0.00%	20		1987
M1A2	N/A	N/A	N/A	5	32	15.63%	-2	19	-10.53%	3	51	5.88%	54		1990
M1A2 UPGRADE	N/A	N/A	N/A	0	64	0.00%	4	14	28.57%	4	78	5.13%	82		1993
TOTAL	N/A	N/A	N/A	6	165	17.07%	5	59	68.05%	11	224	16.34%	235		
AVERAGE	N/A	N/A	N/A	2.00	55.00	5.69%	1.25	14.75	17.01%	2.75	56	4.09%	58.75		
OVERALL TOTAL	7	53	13.21%	120	615	880.25%	-70	250	206.82%	57	918	291.71%	975		
OVERALL AVERAGE	7	53	13.21%	9.23	47.31	67.71%	-5.00	17.86	14.77%	4.07	65.57	20.84%	69.6		
# PROGRAMS	14	13													

Table A3. CTAT Raw Cycle Time Data

ProgramName	Mod/NS	Doc Date	Status	MSI	MSII	MSIIIb	END
C31							
AFATDS	-	12-01-1990	NS	05-1984	07-1989	04-1994	01-1995
AFATDS	-	12-01-1991	NS	05-1984	07-1989	06-1994	09-1995
AFATDS	-	12-01-1992	NS	05-1984	07-1989	06-1994	09-1995
AFATDS	-	12-01-1993	NS	05-1984	07-1989	12-1994	12-1995
AFATDS	-	12-01-1994	NS	05-1984	07-1989	11-1995	07-1996
AFATDS	-	12-01-1995	NS	05-1984	07-1989	12-1995	08-1996
AFATDS	-	12-01-1996	NS	05-1984	09-1989	12-1995	01-1997
AFATDS	-	12-01-1997	NS	05-1984	09-1989	12-1995	01-1997
AN/TTC-39	-	12-01-1974	NS	06-1972	04-1974	03-1981	03-1981
AN/TTC-39	-	12-01-1975	NS	06-1972	04-1974	08-1981	08-1981
AN/TTC-39	-	12-01-1976	NS	06-1972	04-1974	12-1982	06-1982
AN/TTC-39	-	12-01-1977	NS	06-1972	04-1974	12-1982	06-1982
AN/TTC-39	-	12-01-1978	NS	06-1972	04-1974	10-1981	06-1982
AN/TTC-39	-	12-01-1979	NS	06-1972	04-1974	10-1981	12-1982
AN/TTC-39	-	12-01-1980	NS	06-1972	04-1974	07-1980	02-1983
AN/TTC-39	-	12-01-1981	NS	06-1972	04-1974	07-1980	03-1983
AN/TTC-39	-	12-01-1982	NS	06-1972	04-1974	07-1980	03-1983
AN/TTC-39	-	12-01-1983	NS	06-1972	04-1974	07-1980	03-1983
AN/TTC-39	-	12-01-1984	NS	06-1972	04-1974	07-1980	03-1983
SCAMP	-	12-01-1992	NS	12-1991	05-1992	02-1996	12-1997
SCAMP	-	12-01-1993	NS	12-1991	05-1992	02-1996	12-1997
SCAMP	-	12-01-1994	NS	12-1991	05-1992	11-1994	12-1997
SMART-T	-	12-01-1992	NS	02-1991	05-1992	10-1998	12-1999
SMART-T	-	12-01-1993	NS	02-1991	05-1992	10-1998	12-1999
SMART-T	-	12-01-1994	NS	02-1991	05-1992	10-1998	12-1999
SMART-T	-	12-01-1995	NS	02-1991	05-1992	10-1998	12-1999
SMART-T	-	12-01-1996	NS	02-1991	05-1992	10-1998	12-1999
SMART-T	-	12-01-1997	NS	02-1991	05-1992	11-1998	12-1999
Longbow Apache	-	12-01-1989	NS	08-1985	07-1990	05-1994	05-1996
Longbow Apache	-	12-01-1990	NS	08-1985	12-1990	12-1996	04-1997
Longbow Apache	-	12-01-1991	NS	08-1985	12-1990	10-1996	04-1997
Longbow Apache	-	12-01-1992	NS	08-1985	12-1990	10-1997	12-1997
Longbow Apache	-	12-01-1993	NS	08-1985	12-1990	11-1995	12-1997
Longbow Apache	-	12-01-1994	NS	08-1985	12-1990	10-1995	12-1997
Longbow Apache	-	12-01-1995	NS	08-1985	12-1990	10-1995	12-1997
Longbow Apache	-	12-01-1996	NS	08-1985	12-1990	10-1995	10-1998
Longbow Apache	-	12-01-1997	NS	08-1985	12-1990	10-1995	10-1998

Table A4. CTAT Raw Cycle Time Data

ProgramName	Mod/NS	Doc Date	Status	MSI	MSII	MSIIIb	END
HELICOPTERS							
AH-64 (Apache)	-	12-01-1973	NS	09-1972	05-1976	TBD	02-1985
AH-64 (Apache)	-	12-01-1974	NS	09-1972	11-1976	TBD	TBD
AH-64 (Apache)	-	12-01-1975	NS	09-1972	11-1976	10-1980	02-1985
AH-64 (Apache)	-	12-01-1976	NS	09-1972	12-1976	05-1980	09-1984
AH-64 (Apache)	-	12-01-1977	NS	09-1972	12-1976	11-1980	03-1985
AH-64 (Apache)	-	12-01-1978	NS	09-1972	12-1976	11-1980	03-1985
AH-64 (Apache)	-	12-01-1979	NS	09-1972	12-1976	11-1981	03-1986
AH-64 (Apache)	-	12-01-1980	NS	09-1972	12-1976	12-1981	01-1985
AH-64 (Apache)	-	12-01-1981	NS	09-1972	12-1976	03-1982	07-1985
AH-64 (Apache)	-	12-01-1982	NS	09-1972	12-1976	03-1982	07-1985
AH-64 (Apache)	-	12-01-1983	NS	09-1972	12-1976	03-1982	08-1985
AH-64 (Apache)	-	12-01-1984	NS	09-1972	12-1976	03-1982	04-1986
AH-64 (Apache)	-	12-01-1985	NS	09-1972	12-1976	03-1982	08-1986
AH-64 (Apache)	-	12-01-1986	NS	09-1972	12-1976	03-1982	07-1986
AH-64 (Apache)	-	12-01-1987	NS	09-1972	12-1976	03-1982	07-1986
AH-64 (Apache)	-	12-01-1988	NS	09-1972	12-1976	03-1982	07-1986
AH-64 (Apache)	-	12-01-1989	NS	09-1972	12-1976	03-1982	07-1986
AH-64 (Apache)	-	12-01-1990	NS	09-1972	12-1976	03-1982	07-1986
AH-64 (Apache)	-	12-01-1991	NS	09-1972	12-1976	03-1982	07-1986
AH-64 (Apache)	-	12-01-1992	NS	09-1972	12-1976	03-1982	07-1986
RAH-66 (Comanche)	-	12-01-1985	NS	06-1987	06-1987	11-1995	05-1996
RAH-66 (Comanche)	-	12-01-1986	NS	06-1987	06-1987	11-1995	11-1995
RAH-66 (Comanche)	-	12-01-1987	NS	04-1988	12-1990	11-1995	12-1995
RAH-66 (Comanche)	-	12-01-1988	NS	06-1988	12-1990	11-1996	11-1996
RAH-66 (Comanche)	-	12-01-1989	NS	06-1988	12-1990	11-1996	12-1996
RAH-66 (Comanche)	-	12-01-1990	NS	06-1988	09-1994	11-1998	12-1998
RAH-66 (Comanche)	-	12-01-1991	NS	06-1988	TBD	TBD	TBD
RAH-66 (Comanche)	-	12-01-1992	NS	06-1988	10-1997	11-2002	01-2003
RAH-66 (Comanche)	-	12-01-1993	NS	06-1988	10-1997	11-2002	01-2003
RAH-66 (Comanche)	-	12-01-1994	NS	06-1988	10-2001	07-2006	07-2006
RAH-66 (Comanche)	-	12-01-1995	NS	06-1988	10-2001	07-2006	07-2006
RAH-66 (Comanche)	-	12-01-1996	NS	06-1988	10-2001	07-2006	07-2006
RAH-66 (Comanche)	-	12-01-1997	NS	06-1988	10-2001	07-2006	12-2006
UH-60A (Blackhawk)	-	12-01-1972	NS	06-1971	08-1972	04-1977	06-1979
UH-60A (Blackhawk)	-	12-01-1973	NS	06-1971	08-1972	04-1977	06-1979
UH-60A (Blackhawk)	-	12-01-1974	NS	06-1971	10-1976	02-1979	06-1979
UH-60A (Blackhawk)	-	12-01-1975	NS	06-1971	08-1972	08-1979	08-1979
UH-60A (Blackhawk)	-	12-01-1976	NS	06-1971	08-1972	08-1979	08-1979
UH-60A (Blackhawk)	-	12-01-1977	NS	06-1971	08-1972	08-1979	08-1979
UH-60A (Blackhawk)	-	12-01-1978	NS	06-1971	08-1972	09-1979	08-1979
UH-60A (Blackhawk)	-	12-01-1979	NS	06-1971	08-1972	10-1979	11-1979
UH-60A (Blackhawk)	-	12-01-1980	NS	06-1971	08-1972	10-1979	11-1979
UH-60A (Blackhawk)	-	12-01-1981	NS	06-1971	08-1972	10-1979	11-1979

Table A5. CTAT Raw Cycle Time Data

ProgramName	Mod/NS	Doc Date	Status	MSI	MSII	MSIIIb	END
PGM							
ATACMS - BAT	BAT	12-01-1991	NS	02-1985	05-1991	12-1996	01-1998
ATACMS - BAT	BAT	12-01-1992	NS	02-1985	05-1991	11-1998	01-2000
ATACMS - BAT	BAT	12-01-1993	NS	02-1985	05-1991	11-1998	01-2000
ATACMS - BAT	BAT	12-01-1994	NS	02-1985	05-1991	09-2000	07-2002
ATACMS - BAT	BAT	12-01-1995	NS	02-1985	05-1991	09-2000	07-2002
ATACMS - BAT	BAT	12-01-1996	NS	02-1985	05-1991	09-2000	07-2002
ATACMS - BAT	BAT	12-01-1997	NS	02-1985	05-1991	05-2001	09-2002
COPPERHEAD	-	12-01-1975	NS	09-1973	06-1975	11-1979	11-1979
COPPERHEAD	-	12-01-1976	NS	09-1973	06-1975	04-1980	05-1980
COPPERHEAD	-	12-01-1977	NS	09-1973	06-1975	09-1980	09-1980
COPPERHEAD	-	12-01-1978	NS	09-1973	06-1975	12-1980	03-1981
COPPERHEAD	-	12-01-1979	NS	09-1973	06-1975	NA	11-1981
COPPERHEAD	-	12-01-1980	NS	09-1973	06-1975	NA	11-1981
COPPERHEAD	-	12-01-1981	NS	09-1973	06-1975	NA	04-1982
COPPERHEAD	-	12-01-1982	NS	09-1973	06-1975	NA	12-1982
COPPERHEAD	-	12-01-1983	NS	09-1973	06-1975	NA	12-1982
COPPERHEAD	-	12-01-1984	NS	09-1973	06-1975	NA	12-1982
COPPERHEAD	-	12-01-1985	NS	09-1973	06-1975	NA	12-1982
COPPERHEAD	-	12-01-1986	NS	09-1973	06-1975	NA	12-1982
COPPERHEAD	-	12-01-1987	NS	09-1973	06-1975	NA	12-1982
COPPERHEAD	-	12-01-1988	NS	09-1973	06-1975	12-1983	12-1982
SADARM	-	12-01-1991	NS	11-1984	03-1988	06-1994	07-1994
SADARM	-	12-01-1992	NS	11-1984	03-1988	06-1995	09-1995
SADARM	-	12-01-1993	NS	11-1984	03-1988	09-1997	03-1998
SADARM	-	12-01-1994	NS	11-1984	03-1988	12-1998	07-1999
SADARM	-	12-01-1995	NS	11-1984	03-1988	12-1998	07-1999
SADARM	-	12-01-1996	NS	11-1984	03-1988	12-1998	07-1999
SADARM	-	12-01-1997	NS	11-1984	03-1988	12-1998	07-1999

Table A6. CTAT Raw Cycle Time Data

ProgramName	Mod/NS	Doc Date	Status	MSI	MSII	MSIIIb	END
TACTICAL MISSILE							
AAWS-M (Javelin)	-	12-01-1989	NS	05-1986	06-1989	06-1994	12-1995
AAWS-M (Javelin)	-	12-01-1990	NS	05-1986	06-1989	06-1994	12-1995
AAWS-M (Javelin)	-	12-01-1991	NS	05-1986	06-1989	04-1996	01-1997
AAWS-M (Javelin)	-	12-01-1992	NS	05-1986	06-1989	04-1996	01-1997
AAWS-M (Javelin)	-	12-01-1993	NS	05-1986	06-1989	01-1996	01-1997
AAWS-M (Javelin)	-	12-01-1994	NS	05-1986	06-1989	NA	08-1996
AAWS-M (Javelin)	-	12-01-1995	NS	05-1986	06-1989	NA	08-1996
AAWS-M (Javelin)	-	12-01-1996	NS	05-1986	06-1989	NA	10-1996
AAWS-M (Javelin)	-	12-01-1997	NS	05-1986	06-1989	05-1997	10-1996
AGM-114 (Hellfire)	-	12-01-1976	NS	12-1972	02-1976	11-1981	05-1983
AGM-114 (Hellfire)	-	12-01-1977	NS	12-1972	02-1976	01-1982	11-1983
AGM-114 (Hellfire)	-	12-01-1978	NS	12-1972	02-1976	01-1982	11-1983
AGM-114 (Hellfire)	-	12-01-1979	NS	12-1972	02-1976	NA	10-1984
AGM-114 (Hellfire)	-	12-01-1980	NS	12-1972	02-1976	NA	01-1985
AGM-114 (Hellfire)	-	12-01-1981	NS	12-1972	02-1976	NA	07-1985
AGM-114 (Hellfire)	-	12-01-1982	NS	12-1972	02-1976	03-1982	07-1985
AGM-114 (Hellfire)	-	12-01-1983	NS	12-1972	02-1976	03-1982	07-1985
AGM-114 (Hellfire)	-	12-01-1984	NS	12-1972	02-1976	03-1982	04-1986
AGM-114 (Hellfire)	-	12-01-1985	NS	12-1972	02-1976	03-1982	08-1986
AGM-114 (Hellfire)	-	12-01-1986	NS	12-1972	02-1976	03-1982	07-1986
AGM-114 (Hellfire)	-	12-01-1987	NS	12-1972	02-1976	03-1982	07-1986
AGM-114 (Hellfire)	-	12-01-1988	NS	12-1972	02-1976	03-1982	07-1986
AGM-114 (Hellfire)	-	12-01-1989	NS	12-1972	02-1976	03-1982	07-1986
AGM-114 (Hellfire)	-	12-01-1990	NS	12-1972	02-1976	03-1982	07-1986
AGM-114 (Hellfire)	-	12-01-1991	NS	12-1972	02-1976	03-1982	07-1986
AGM-114 (Hellfire)	-	12-01-1992	NS	12-1972	02-1976	03-1982	07-1986
AGM-114 (Hellfire)	-	12-01-1993	NS	12-1972	02-1976	03-1982	07-1986
ATACMS/APAM	Block I	12-01-1985	NS	04-1978	02-1986	NA	06-1990
ATACMS/APAM	Block I	12-01-1986	NS	04-1978	02-1986	09-1989	06-1990
ATACMS/APAM	Block I	12-01-1987	NS	04-1978	02-1986	09-1989	06-1990
ATACMS/APAM	Block I	12-01-1988	NS	04-1978	02-1986	02-1990	07-1990
ATACMS/APAM	Block I	12-01-1989	NS	04-1978	02-1986	09-1990	09-1990
ATACMS/APAM	Block I	12-01-1990	NS	04-1978	02-1986	11-1990	08-1990
ATACMS/APAM	Block I	12-01-1991	NS	04-1978	02-1986	11-1990	08-1990
ATACMS/APAM	Block I	12-01-1992	NS	04-1978	02-1986	11-1990	08-1990
ATACMS/APAM	Block I	12-01-1993	NS	04-1978	02-1986	11-1990	08-1990
ATACMS/APAM	Block I	12-01-1994	NS	04-1978	02-1986	11-1990	08-1990
ATACMS/APAM	Block I	12-01-1995	NS	04-1978	02-1986	11-1990	08-1990
LANCE	-	12-01-1969	NS	01-1963	12-1967	08-1970	06-1972
LANCE	-	12-01-1970	NS	01-1963	12-1967	01-1971	06-1972
LANCE	-	12-01-1971	NS	01-1963	12-1967	01-1971	06-1972
LANCE	-	12-01-1972	NS	01-1963	12-1967	01-1971	06-1972
LANCE	-	12-01-1973	NS	01-1963	12-1967	01-1971	06-1972
LANCE	-	12-01-1974	NS	01-1963	12-1967	01-1971	06-1972
LANCE	-	12-01-1975	NS	01-1963	12-1967	04-1971	06-1972
LANCE	-	12-01-1976	NS	01-1963	12-1967	01-1971	06-1972
LANCE	-	12-01-1977	NS	01-1963	12-1967	01-1971	06-1972

Table A7. CTAT Raw Cycle Time Data

ProgramName	Mod/NS	Doc Date	Status	MSI	MSII	MSIIIb	END
TACTICAL MISSILE							
Longbow Hellfire	-	12-01-1990	NS	08-1985	12-1990	12-1996	04-1997
Longbow Hellfire	-	02-01-1991	NS	08-1985	12-1990	12-1996	04-1997
Longbow Hellfire	-	12-01-1992	NS	08-1985	12-1990	12-1997	01-1998
Longbow Hellfire	-	12-01-1993	NS	08-1985	12-1990	12-1997	01-1998
Longbow Hellfire	-	12-01-1994	NS	08-1985	12-1990	12-1997	01-1998
Longbow Hellfire	-	12-01-1995	NS	08-1985	12-1990	10-1995	12-1997
Longbow Hellfire	-	12-01-1996	NS	08-1985	12-1990	10-1995	07-1998
Longbow Hellfire	-	12-01-1997	NS	08-1985	12-1990	10-1997	07-1998

Table A8. CTAT Raw Cycle Time Data

ProgramName	Mod/NS	Doc Date	Status	MSI	MSII	MSIIIb	END
VEHICLES							
Crusader	-	12-01-1994	NS	11-1994	NA	09-2006	01-2008
Crusader	-	12-01-1995	NS	11-1994	NA	09-2006	01-2008
Crusader	-	12-01-1996	NS	11-1994	03-2001	09-2006	01-2008
Crusader	-	12-01-1997	NS	11-1994	10-2000	11-2005	09-2005
M1 Abrams	M1	12-01-1978	NS	11-1972	11-1976	02-1981	12-1980
M1 Abrams	M1	12-01-1979	NS	11-1972	11-1976	06-1981	12-1980
M1 Abrams	M1	12-01-1980	NS	11-1972	11-1976	10-1981	01-1981
M1 Abrams	M1	12-01-1981	NS	11-1972	11-1976	10-1981	01-1981
M1 Abrams	M1	12-01-1982	NS	11-1972	11-1976	10-1981	01-1981
M1 Abrams	M1	12-01-1983	NS	11-1972	11-1976	10-1981	01-1981
M1 Abrams	M1	12-01-1984	NS	11-1972	11-1976	10-1981	01-1981
M1 Abrams	M1	12-01-1985	NS	11-1972	11-1976	10-1981	01-1981
M1 Abrams	M1	12-01-1986	NS	11-1972	11-1976	10-1981	01-1981
MICV (Bradley)	-	12-01-1973	NS	04-1972	11-1972	NA	08-1978
MICV (Bradley)	-	12-01-1974	NS	04-1972	11-1972	NA	03-1979
MICV (Bradley)	-	12-01-1975	NS	04-1972	11-1972	NA	11-1979
MICV (Bradley)	-	12-01-1976	NS	04-1972	11-1972	NA	07-1982
MICV (Bradley)	-	12-01-1977	NS	04-1972	11-1972	NA	07-1982
MICV (Bradley)	-	12-01-1978	NS	04-1972	11-1972	01-1980	07-1982
MICV (Bradley)	-	12-01-1979	NS	04-1972	11-1972	01-1980	10-1982
MICV (Bradley)	-	12-01-1980	NS	04-1972	11-1972	01-1980	10-1982
MICV (Bradley)	-	12-01-1981	NS	04-1972	11-1972	01-1980	10-1983
MICV (Bradley)	-	12-01-1982	NS	04-1972	11-1972	01-1980	10-1983
MICV (Bradley)	-	12-01-1983	NS	04-1972	11-1972	01-1980	10-1983
MICV (Bradley)	-	12-01-1984	NS	04-1972	11-1972	01-1980	10-1983
MICV (Bradley)	-	12-01-1985	NS	04-1972	11-1972	01-1980	10-1983
MICV (Bradley)	-	12-01-1986	NS	04-1972	11-1972	01-1980	10-1983
MICV (Bradley)	-	12-01-1987	NS	04-1972	11-1972	01-1980	10-1983
MICV (Bradley)	-	12-01-1988	NS	04-1972	11-1972	01-1980	10-1983
MICV (Bradley)	-	12-01-1989	NS	04-1972	11-1972	01-1980	10-1983
MICV (Bradley)	-	12-01-1990	NS	04-1972	11-1972	01-1980	10-1983
MICV (Bradley)	-	12-01-1991	NS	04-1972	11-1972	01-1980	10-1983
MICV (Bradley)	-	12-01-1992	NS	04-1972	11-1972	01-1980	10-1983
PLS (FHTV)	-	12-01-1988	NS	05-1987	05-1988	04-1990	01-1992
PLS (FHTV)	-	12-01-1989	NS	05-1987	05-1988	03-1992	04-1992
PLS (FHTV)	-	12-01-1990	NS	05-1987	05-1988	08-1992	10-1992
PLS (FHTV)	-	12-01-1991	NS	05-1987	05-1988	11-1992	02-1993
PLS (FHTV)	-	12-01-1992	NS	05-1987	05-1988	12-1992	09-1993
PLS (FHTV)	-	12-01-1993	NS	05-1987	05-1988	12-1992	03-1994
PLS (FHTV)	-	12-01-1994	NS	05-1987	05-1988	12-1992	02-1994
PLS (FHTV)	-	12-01-1995	NS	05-1987	05-1988	12-1992	02-1994
PLS (FHTV)	-	12-01-1996	NS	05-1987	05-1988	12-1992	02-1994

Table A9. CTAT Raw Cycle Time Data (Modifications)

ProgramName	Mod/NS	Doc Date	Status	MSI	MSII	MSIIIb	END
VEHICLES							
BFVS/A3 Upgrade	A3 Upgrade	12-01-1993	Mod	NA	01-1994	10-1999	04-2000
BFVS/A3 Upgrade	A3 Upgrade	12-01-1994	Mod	NA	01-1994	11-1999	08-2000
BFVS/A3 Upgrade	A3 Upgrade	12-01-1995	Mod	NA	01-1994	11-1999	08-2000
BFVS/A3 Upgrade	A3 Upgrade	12-01-1996	Mod	NA	01-1994	11-1999	06-2000
BFVS/A3 Upgrade	A3 Upgrade	12-01-1997	Mod	NA	01-1994	11-1999	08-2000
M1 Abrams	M1A1	12-01-1987	Mod	NA	NA	04-1985	12-1986
M1 Abrams	M1A1	12-01-1988	Mod	NA	NA	04-1985	12-1986
M1 Abrams	M1A1	12-01-1989	Mod	NA	NA	04-1985	12-1986
M1 Abrams	M1A2	12-02-1988	Mod	NA	12-1988	08-1991	03-1993
M1 Abrams	M1A2	12-02-1989	Mod	NA	12-1988	01-1992	06-1993
M1 Abrams	M1A2	12-01-1990	Mod	NA	12-1988	01-1992	06-1993
M1 Abrams	M1A2	12-01-1991	Mod	NA	12-1988	NA	02-1993
M1 Abrams	UPGRADE	12-02-1992	Mod	NA	12-1988	04-1994	06-1995
M1 Abrams	UPGRADE	12-01-1993	Mod	NA	12-1988	04-1994	06-1995
M1 Abrams	UPGRADE	12-01-1994	Mod	NA	12-1988	04-1994	06-1995
M1 Abrams	UPGRADE	12-01-1995	Mod	NA	12-1988	04-1994	10-1995
M1 Abrams	UPGRADE	12-01-1996	Mod	NA	12-1988	04-1994	10-1995
M1 Abrams	UPGRADE	12-01-1997	Mod	NA	12-1988	04-1994	10-1995

Table A10. CTAT Raw Cycle Time Data (Modifications)

ProgramName	Mod/NS	Doc Date	Status	MSI	MSII	MSIIIb	END
PGM							
ATACMS - BAT	BAT P3I	12-04-1994	Mod	10-1993	03-1998	02-2002	02-2003
ATACMS - BAT	BAT P3I	12-04-1995	Mod	10-1993	03-1998	02-2002	02-2003
ATACMS - BAT	BAT P3I	12-04-1996	Mod	10-1993	10-1998	06-2002	02-2003
ATACMS - BAT	BAT P3I	12-04-1997	Mod	10-1993	10-1998	06-2002	10-2002
ATACMS - BAT	Block II	12-02-1994	Mod	NA	05-1995	09-2000	09-2000
ATACMS - BAT	Block II	12-02-1995	Mod	NA	05-1995	09-2000	09-2000
ATACMS - BAT	Block II	12-02-1996	Mod	NA	05-1990	09-2000	09-2000
ATACMS - BAT	Block II	12-02-1997	Mod	NA	05-1995	05-2001	09-2001
ATACMS - BAT	Block IIA	12-03-1994	Mod	NA	03-1998	02-2002	05-2003
ATACMS - BAT	Block IIA	12-03-1995	Mod	NA	04-1998	02-2002	05-2003
ATACMS - BAT	Block IIA	12-03-1996	Mod	NA	03-1999	12-2003	03-2004
ATACMS - BAT	Block IIA	12-03-1997	Mod	NA	03-1999	12-2003	03-2004
C3I							
ASAS	Block II	12-02-1991	Mod	NA	01-1993	11-1997	08-2002
ASAS	Block II	12-02-1992	Mod	NA	08-1993	07-1999	08-2001
ASAS	Block II	12-02-1993	Mod	NA	08-1993	07-1999	12-1999
ASAS	Block II	12-02-1994	Mod	NA	10-1993	07-1999	12-1999
ASAS	Block II	12-02-1995	Mod	NA	10-1993	07-1999	12-1999
ASAS	Block II	12-02-1996	Mod	NA	10-1993	04-1999	06-2000
ASAS	Block II	12-02-1997	Mod	NA	10-1993	03-2000	09-2000
MCS	Block III	12-03-1991	Mod	NA	04-1993	12-1993	12-1994
MCS	Block III	12-03-1992	Mod	NA	04-1993	NA	NA
MCS	Block III	12-03-1993	Mod	NA	04-1993	NA	NA
MCS	Block III	12-03-1994	Mod	NA	04-1993	06-1997	11-1997
MCS	Block III	12-03-1995	Mod	NA	04-1993	06-1997	06-1998
MCS	Block III	12-03-1996	Mod	NA	04-1993	09-1998	02-1999
MCS	Block III	12-01-1997	Mod	NA	04-1993	12-1998	02-1999

Table A11. CTAT Raw Cycle Time Data (Modifications)

ProgramName	Mod/NS	Doc Date	Status	MSI	MSII	MSIIIb	END
TAC MISSILE							
AGM-114 (Hellfire)	HOMS	12-02-1992	Mod	NA	07-1989	05-1993	12-1994
AGM-114 (Hellfire)	HOMS	12-02-1993	Mod	NA	07-1989	05-1993	12-1994
STINGER - RMP	RMP	12-01-1983	Mod	NA	06-1983	11-1986	08-1987
STINGER - RMP	RMP	12-01-1984	Mod	NA	09-1984	11-1986	12-1987
STINGER - RMP	RMP	12-01-1985	Mod	NA	09-1984	11-1986	11-1987
STINGER - RMP	RMP	12-01-1986	Mod	NA	09-1984	11-1986	03-1988
STINGER - RMP	RMP	12-01-1987	Mod	NA	09-1984	11-1986	06-1988
STINGER - RMP	RMP	12-01-1988	Mod	NA	09-1984	11-1986	04-1989
STINGER - RMP	RMP	12-01-1989	Mod	NA	09-1984	03-1988	11-1989
STINGER - RMP	RMP	12-01-1990	Mod	NA	09-1984	03-1988	11-1989
STINGER - RMP	RMP	12-01-1991	Mod	NA	09-1984	03-1988	11-1989
STINGER - RMP	RMP	12-01-1992	Mod	NA	09-1984	03-1988	11-1989
STINGER - RMP	RMP	12-01-1993	Mod	NA	09-1984	03-1988	11-1989
STINGER - RMP	RMP	12-01-1994	Mod	NA	09-1984	03-1988	11-1989
ATACMS/APAM	BL 1A	12-02-1993	Mod	NA	02-1994	01-1997	02-1998
ATACMS/APAM	BL 1A	12-03-1994	Mod	NA	02-1994	10-1997	02-1998
ATACMS/APAM	BL 1A	12-02-1995	Mod	NA	02-1994	03-1997	02-1998
ATACMS/APAM	BL 1A	12-01-1996	Mod	NA	02-1994	03-1997	08-1997
ATACMS/APAM	BL 1A	12-01-1997	Mod	NA	02-1994	03-1998	02-1998

Table A12. CTAT Raw Cycle Time Data (Modifications)

ProgramName	Mod/NS	Doc Date	Status	MSI	MSII	MSIIIb	END
HELICOPTER							
CH-47D (Chinook)	D Model	12-01-1978	Mod	NA	10-1975	09-1980	02-1984
CH-47D (Chinook)	D Model	12-01-1979	Mod	NA	10-1975	09-1980	02-1984
CH-47D (Chinook)	D Model	12-01-1980	Mod	NA	10-1975	10-1980	02-1985
CH-47D (Chinook)	D Model	12-01-1981	Mod	NA	10-1975	10-1980	02-1984
CH-47D (Chinook)	D Model	12-01-1982	Mod	NA	10-1975	10-1980	02-1984
CH-47D (Chinook)	D Model	12-01-1983	Mod	NA	10-1975	10-1980	02-1984
CH-47D (Chinook)	D Model	12-01-1984	Mod	NA	10-1975	10-1980	02-1984
CH-47D (Chinook)	D Model	12-01-1985	Mod	NA	10-1975	10-1980	02-1984
CH-47D (Chinook)	D Model	12-01-1986	Mod	NA	10-1975	10-1980	02-1984
CH-47D (Chinook)	D Model	12-01-1987	Mod	NA	10-1975	10-1980	02-1984
CH-47D (Chinook)	D Model	12-01-1988	Mod	NA	10-1975	10-1980	02-1984
CH-47D (Chinook)	D Model	12-01-1989	Mod	NA	10-1975	10-1980	02-1984
CH-47D (Chinook)	D Model	12-01-1990	Mod	NA	10-1975	10-1980	02-1984
CH-47D (Chinook)	D Model	12-01-1991	Mod	NA	10-1975	10-1980	02-1984
CH-47D (Chinook)	D Model	12-01-1992	Mod	NA	10-1975	10-1980	02-1984
KIOWA Warrior	-	12-01-1982	Mod	NA	09-1981	06-1985	07-1986
KIOWA Warrior	-	12-01-1983	Mod	NA	09-1981	06-1985	07-1986
KIOWA Warrior	-	12-01-1984	Mod	NA	09-1981	06-1985	07-1986
KIOWA Warrior	-	12-01-1985	Mod	NA	09-1981	06-1985	07-1987
KIOWA Warrior	-	12-01-1986	Mod	NA	09-1981	06-1985	07-1987
KIOWA Warrior	-	12-01-1987	Mod	NA	09-1981	10-1985	05-1987
KIOWA Warrior	-	12-01-1988	Mod	NA	09-1981	10-1985	05-1987
KIOWA Warrior	-	12-01-1989	Mod	NA	09-1981	10-1985	05-1987
KIOWA Warrior	-	12-01-1991	Mod	NA	09-1981	10-1985	05-1987
KIOWA Warrior	-	12-01-1992	Mod	NA	09-1981	10-1985	05-1987
KIOWA Warrior	-	12-01-1993	Mod	NA	09-1981	10-1985	05-1987
KIOWA Warrior	-	12-01-1994	Mod	NA	09-1981	10-1985	05-1987
KIOWA Warrior	-	12-01-1995	Mod	NA	09-1981	10-1985	05-1987

Table A13. CTAT Raw Cycle Time Data

ProgramName	PrgmStart-IOC	MSI-IOC	MSI-MSII	MSI-MSIII	MSII-IOC	MSII-MSIII	MSIII-IOC
C31							
AFATDS	128	128	62	119	66	57	9
AFATDS	136	136	62	121	74	59	15
AFATDS	136	136	62	121	74	59	15
AFATDS	139	139	62	127	77	65	12
AFATDS	146	146	62	138	84	76	8
AFATDS	147	147	62	139	85	77	8
AFATDS	152	152	64	139	88	75	13
AFATDS	152	152	64	139	88	75	13
AN/TTC-39	105	105	22	105	83	83	0
AN/TTC-39	110	110	22	110	88	88	0
AN/TTC-39	120	120	22	126	98	104	-6
AN/TTC-39	120	120	22	126	98	104	-6
AN/TTC-39	120	120	22	112	98	90	8
AN/TTC-39	126	126	22	112	104	90	14
AN/TTC-39	128	128	22	97	106	75	31
AN/TTC-39	129	129	22	97	107	75	32
AN/TTC-39	129	129	22	97	107	75	32
AN/TTC-39	129	129	22	97	107	75	32
AN/TTC-39	129	129	22	97	107	75	32
SCAMP	72	72	5	50	67	45	22
SCAMP	72	72	5	50	67	45	22
SCAMP	72	72	5	35	67	30	37
SMART-T	106	106	15	92	91	77	14
SMART-T	106	106	15	92	91	77	14
SMART-T	106	106	15	92	91	77	14
SMART-T	106	106	15	92	91	77	14
SMART-T	106	106	15	92	91	77	14
SMART-T	106	106	15	93	91	78	13
Longbow Apache	129	129	59	105	70	46	24
Longbow Apache	140	140	64	136	76	72	4
Longbow Apache	140	140	64	134	76	70	6
Longbow Apache	148	148	64	146	84	82	2
Longbow Apache	148	148	64	123	84	59	25
Longbow Apache	148	148	64	122	84	58	26
Longbow Apache	148	148	64	122	84	58	26
Longbow Apache	158	158	64	122	94	58	36
Longbow Apache	158	158	64	122	94	58	36

Table A14. CTAT Raw Cycle Time Data

ProgramName	PrgmStart-IOC	MSI-IOC	MSI-MSII	MSI-MSIII	MSII-IOC	MSII-MSIII	MSIII-IOC
HELICOPTERS							
AH-64 (Apache)	149	149	44	0	105	0	0
AH-64 (Apache)	0	0	50	0	0	0	0
AH-64 (Apache)	149	149	50	97	99	47	52
AH-64 (Apache)	144	144	51	92	93	41	52
AH-64 (Apache)	150	150	51	98	99	47	52
AH-64 (Apache)	150	150	51	98	99	47	52
AH-64 (Apache)	162	162	51	110	111	59	52
AH-64 (Apache)	148	148	51	111	97	60	37
AH-64 (Apache)	154	154	51	114	103	63	40
AH-64 (Apache)	154	154	51	114	103	63	40
AH-64 (Apache)	155	155	51	114	104	63	41
AH-64 (Apache)	163	163	51	114	112	63	49
AH-64 (Apache)	167	167	51	114	116	63	53
AH-64 (Apache)	166	166	51	114	115	63	52
AH-64 (Apache)	166	166	51	114	115	63	52
AH-64 (Apache)	166	166	51	114	115	63	52
AH-64 (Apache)	166	166	51	114	115	63	52
AH-64 (Apache)	166	166	51	114	115	63	52
AH-64 (Apache)	166	166	51	114	115	63	52
AH-64 (Apache)	166	166	51	114	115	63	52
RAH-66 (Comanche)	107	107	0	101	107	101	6
RAH-66 (Comanche)	101	101	0	101	101	101	0
RAH-66 (Comanche)	92	92	32	91	60	59	1
RAH-66 (Comanche)	101	101	30	101	71	71	0
RAH-66 (Comanche)	102	102	30	101	72	71	1
RAH-66 (Comanche)	126	126	75	125	51	50	1
RAH-66 (Comanche)	0	0	0	0	0	0	0
RAH-66 (Comanche)	175	175	112	173	63	61	2
RAH-66 (Comanche)	175	175	112	173	63	61	2
RAH-66 (Comanche)	217	217	160	217	57	57	0
RAH-66 (Comanche)	217	217	160	217	57	57	0
RAH-66 (Comanche)	217	217	160	217	57	57	0
RAH-66 (Comanche)	222	222	160	217	62	57	5
UH-60A (Blackhawk)	96	96	14	70	82	56	26
UH-60A (Blackhawk)	96	96	14	70	82	56	26
UH-60A (Blackhawk)	96	96	64	92	32	28	4
UH-60A (Blackhawk)	98	98	14	98	84	84	0
UH-60A (Blackhawk)	98	98	14	98	84	84	0
UH-60A (Blackhawk)	98	98	14	98	84	84	0
UH-60A (Blackhawk)	98	98	14	99	84	85	-1
UH-60A (Blackhawk)	101	101	14	100	87	86	1
UH-60A (Blackhawk)	101	101	14	100	87	86	1
UH-60A (Blackhawk)	101	101	14	100	87	86	1

Table A15. CTAT Raw Cycle Time Data

ProgramName	PrgmStart-IOC	MSI-IOC	MSI-MSII	MSI-MSIII	MSII-IOC	MSII-MSIII	MSIII-IOC
PGM							
ATACMS - BAT	155	155	75	142	80	67	13
ATACMS - BAT	179	179	75	165	104	90	14
ATACMS - BAT	179	179	75	165	104	90	14
ATACMS - BAT	209	209	75	187	134	112	22
ATACMS - BAT	209	209	75	187	134	112	22
ATACMS - BAT	209	209	75	187	134	112	22
ATACMS - BAT	211	211	75	195	136	120	16
COPPERHEAD	74	74	21	74	53	53	0
COPPERHEAD	80	80	21	79	59	58	1
COPPERHEAD	84	84	21	84	63	63	0
COPPERHEAD	90	90	21	87	69	66	3
COPPERHEAD	98	98	21	0	77	0	0
COPPERHEAD	98	98	21	0	77	0	0
COPPERHEAD	103	103	21	0	82	0	0
COPPERHEAD	111	111	21	0	90	0	0
COPPERHEAD	111	111	21	0	90	0	0
COPPERHEAD	111	111	21	0	90	0	0
COPPERHEAD	111	111	21	0	90	0	0
COPPERHEAD	111	111	21	0	90	0	0
COPPERHEAD	111	111	21	0	90	0	0
COPPERHEAD	111	111	21	123	90	102	-12
SADARM	116	116	40	115	76	75	1
SADARM	130	130	40	127	90	87	3
SADARM	160	160	40	154	120	114	6
SADARM	176	176	40	169	136	129	7
SADARM	176	176	40	169	136	129	7
SADARM	176	176	40	169	136	129	7
SADARM	176	176	40	169	136	129	7

Table A16. CTAT Raw Cycle Time Data

ProgramName	PrgmStart-IOC	MSI-IOC	MSI-MSII	MSI-MSIII	MSII-IOC	MSII-MSIII	MSIII-IOC
TACTICAL MISSILE							
AAWS-M (Javelin)	115	115	37	97	78	60	18
AAWS-M (Javelin)	115	115	37	97	78	60	18
AAWS-M (Javelin)	128	128	37	119	91	82	9
AAWS-M (Javelin)	128	128	37	119	91	82	9
AAWS-M (Javelin)	128	128	37	116	91	79	12
AAWS-M (Javelin)	123	123	37	0	86	0	0
AAWS-M (Javelin)	123	123	37	0	86	0	0
AAWS-M (Javelin)	125	125	37	0	88	0	0
AAWS-M (Javelin)	125	125	37	132	88	95	-7
AGM-114 (Hellfire)	125	125	38	107	87	69	18
AGM-114 (Hellfire)	131	131	38	109	93	71	22
AGM-114 (Hellfire)	131	131	38	109	93	71	22
AGM-114 (Hellfire)	142	142	38	0	104	0	0
AGM-114 (Hellfire)	145	145	38	0	107	0	0
AGM-114 (Hellfire)	151	151	38	0	113	0	0
AGM-114 (Hellfire)	151	151	38	111	113	73	40
AGM-114 (Hellfire)	151	151	38	111	113	73	40
AGM-114 (Hellfire)	160	160	38	111	122	73	49
AGM-114 (Hellfire)	164	164	38	111	126	73	53
AGM-114 (Hellfire)	163	163	38	111	125	73	52
AGM-114 (Hellfire)	163	163	38	111	125	73	52
AGM-114 (Hellfire)	163	163	38	111	125	73	52
AGM-114 (Hellfire)	163	163	38	111	125	73	52
AGM-114 (Hellfire)	163	163	38	111	125	73	52
AGM-114 (Hellfire)	163	163	38	111	125	73	52
AGM-114 (Hellfire)	163	163	38	111	125	73	52
AGM-114 (Hellfire)	163	163	38	111	125	73	52
ATACMS/APAM	146	146	94	0	52	0	0
ATACMS/APAM	146	146	94	137	52	43	9
ATACMS/APAM	146	146	94	137	52	43	9
ATACMS/APAM	147	147	94	142	53	48	5
ATACMS/APAM	149	149	94	149	55	55	0
ATACMS/APAM	148	148	94	151	54	57	-3
ATACMS/APAM	148	148	94	151	54	57	-3
ATACMS/APAM	148	148	94	151	54	57	-3
ATACMS/APAM	148	148	94	151	54	57	-3
ATACMS/APAM	148	148	94	151	54	57	-3
ATACMS/APAM	148	148	94	151	54	57	-3
LANCE	113	113	59	91	54	32	22
LANCE	113	113	59	96	54	37	17
LANCE	113	113	59	96	54	37	17
LANCE	113	113	59	96	54	37	17
LANCE	113	113	59	96	54	37	17
LANCE	113	113	59	96	54	37	17
LANCE	113	113	59	99	54	40	14
LANCE	113	113	59	96	54	37	17
LANCE	113	113	59	96	54	37	17

Table A17. CTAT Raw Cycle Time Data

ProgramName	PrgmStart-IOC	MSI-IOC	MSI-MSII	MSI-MSIII	MSII-IOC	MSII-MSIII	MSIII-IOC
TACTICAL MISSILE							
Longbow Hellfire	140	140	64	136	76	72	4
Longbow Hellfire	140	140	64	136	76	72	4
Longbow Hellfire	149	149	64	148	85	84	1
Longbow Hellfire	149	149	64	148	85	84	1
Longbow Hellfire	149	149	64	148	85	84	1
Longbow Hellfire	148	148	64	122	84	58	26
Longbow Hellfire	155	155	64	122	91	58	33
Longbow Hellfire	155	155	64	146	91	82	9

Table A18. CTAT Raw Cycle Time Data

ProgramName	PrgmStart-IOC	MSI-IOC	MSI-MSII	MSI-MSIII	MSII-IOC	MSII-MSIII	MSIII-IOC
VEHICLES							
Crusader	158	158	0	142	0	0	16
Crusader	158	158	0	142	0	0	16
Crusader	158	158	76	142	82	66	16
Crusader	130	130	71	132	59	61	-2
M1 Abrams	97	97	48	99	49	51	-2
M1 Abrams	97	97	48	103	49	55	-6
M1 Abrams	98	98	48	107	50	59	-9
M1 Abrams	98	98	48	107	50	59	-9
M1 Abrams	98	98	48	107	50	59	-9
M1 Abrams	98	98	48	107	50	59	-9
M1 Abrams	98	98	48	107	50	59	-9
M1 Abrams	98	98	48	107	50	59	-9
M1 Abrams	98	98	48	107	50	59	-9
MICV (Bradley)	76	76	7	0	69	0	0
MICV (Bradley)	83	83	7	0	76	0	0
MICV (Bradley)	91	91	7	0	84	0	0
MICV (Bradley)	123	123	7	0	116	0	0
MICV (Bradley)	123	123	7	0	116	0	0
MICV (Bradley)	123	123	7	93	116	86	30
MICV (Bradley)	126	126	7	93	119	86	33
MICV (Bradley)	126	126	7	93	119	86	33
MICV (Bradley)	138	138	7	93	131	86	45
MICV (Bradley)	138	138	7	93	131	86	45
MICV (Bradley)	138	138	7	93	131	86	45
MICV (Bradley)	138	138	7	93	131	86	45
MICV (Bradley)	138	138	7	93	131	86	45
MICV (Bradley)	138	138	7	93	131	86	45
MICV (Bradley)	138	138	7	93	131	86	45
MICV (Bradley)	138	138	7	93	131	86	45
MICV (Bradley)	138	138	7	93	131	86	45
MICV (Bradley)	138	138	7	93	131	86	45
MICV (Bradley)	138	138	7	93	131	86	45
MICV (Bradley)	138	138	7	93	131	86	45
PLS (FHTV)	56	56	12	35	44	23	21
PLS (FHTV)	59	59	12	58	47	46	1
PLS (FHTV)	65	65	12	63	53	51	2
PLS (FHTV)	69	69	12	66	57	54	3
PLS (FHTV)	76	76	12	67	64	55	9
PLS (FHTV)	82	82	12	67	70	55	15
PLS (FHTV)	81	81	12	67	69	55	14
PLS (FHTV)	81	81	12	67	69	55	14
PLS (FHTV)	81	81	12	67	69	55	14

Table A19. CTAT Raw Cycle Time Data (Modifications)

ProgramName	PrgmStart-IOC	MSI-IOC	MSI-MSII	MSI-MSIII	MSII-IOC	MSII-MSIII	MSIII-IOC
VEHICLES							
BFVS/A3 Upgrade	75	0	0	0	75	69	6
BFVS/A3 Upgrade	79	0	0	0	79	70	9
BFVS/A3 Upgrade	79	0	0	0	79	70	9
BFVS/A3 Upgrade	77	0	0	0	77	70	7
BFVS/A3 Upgrade	79	0	0	0	79	70	9
M1 Abrams A1	20	0	0	0	0	0	20
M1 Abrams A1	20	0	0	0	0	0	20
M1 Abrams A1	20	0	0	0	0	0	20
M1 Abrams A2	51	0	0	0	51	32	19
M1 Abrams A2	54	0	0	0	54	37	17
M1 Abrams A2	54	0	0	0	54	37	17
M1 Abrams A2	50	0	0	0	50	0	0
M1 Abrams Upgrade	78	0	0	0	78	64	14
M1 Abrams Upgrade	78	0	0	0	78	64	14
M1 Abrams Upgrade	78	0	0	0	78	64	14
M1 Abrams Upgrade	82	0	0	0	82	64	18
M1 Abrams Upgrade	82	0	0	0	82	64	18
M1 Abrams Upgrade	82	0	0	0	82	64	18

Table A20. CTAT Raw Cycle Time Data (Modifications)

ProgramName	PrgmStart-IOC	MSI-IOC	MSI-MSII	MSI-MSIII	MSII-IOC	MSII-MSIII	MSIII-IOC
PGM							
ATACMS - BAT	112	112	53	100	59	47	12
ATACMS - BAT	112	112	53	100	59	47	12
ATACMS - BAT	112	112	60	104	52	44	8
ATACMS - BAT	108	108	60	104	48	44	4
ATACMS - BAT	64	0	0	0	64	64	0
ATACMS - BAT	64	0	0	0	64	64	0
ATACMS - BAT	124	0	0	0	124	124	0
ATACMS - BAT	76	0	0	0	76	72	4
ATACMS - BAT	62	0	0	0	62	47	15
ATACMS - BAT	61	0	0	0	61	46	15
ATACMS - BAT	60	0	0	0	60	57	3
ATACMS - BAT	60	0	0	0	60	57	3
C3I							
ASAS	115	0	0	0	115	58	57
ASAS	96	0	0	0	96	71	25
ASAS	76	0	0	0	76	71	5
ASAS	74	0	0	0	74	69	5
ASAS	74	0	0	0	74	69	5
ASAS	80	0	0	0	80	66	14
ASAS	83	0	0	0	83	77	6
MCS	20	0	0	0	20	8	12
MCS	0	0	0	0	0	0	0
MCS	0	0	0	0	0	0	0
MCS	55	0	0	0	55	50	5
MCS	62	0	0	0	62	50	12
MCS	70	0	0	0	70	65	5
MCS	70	0	0	0	70	68	2

Table A21. CTAT Raw Cycle Time Data (Modifications)

ProgramName	PrgmStart-IOC	MSI-IOC	MSI-MSII	MSI-MSIII	MSII-IOC	MSII-MSIII	MSIII-IOC
TAC MISSILE							
AGM-114 (Hellfire)	65	0	0	0	65	46	19
AGM-114 (Hellfire)	65	0	0	0	65	46	19
STINGER - RMP	50	0	0	0	50	41	9
STINGER - RMP	39	0	0	0	39	26	13
STINGER - RMP	38	0	0	0	38	26	12
STINGER - RMP	42	0	0	0	42	26	16
STINGER - RMP	45	0	0	0	45	26	19
STINGER - RMP	55	0	0	0	55	26	29
STINGER - RMP	62	0	0	0	62	42	20
STINGER - RMP	62	0	0	0	62	42	20
STINGER - RMP	62	0	0	0	62	42	20
STINGER - RMP	62	0	0	0	62	42	20
STINGER - RMP	62	0	0	0	62	42	20
STINGER - RMP	62	0	0	0	62	42	20
ATACMS/APAM	48	0	0	0	48	35	13
ATACMS/APAM	48	0	0	0	48	44	4
ATACMS/APAM	48	0	0	0	48	37	11
ATACMS/APAM	42	0	0	0	42	37	5
ATACMS/APAM	48	0	0	0	48	49	-1

Table A22. CTAT Raw Cycle Time Data (Modifications)

ProgramName	PrgmStart-IOC	MSI-IOC	MSI-MSII	MSI-MSIII	MSII-IOC	MSII-MSIII	MSIII-IOC
Helicopters							
CH-47D (Chinook)	100	0	0	0	100	59	41
CH-47D (Chinook)	100	0	0	0	100	59	41
CH-47D (Chinook)	112	0	0	0	112	60	52
CH-47D (Chinook)	100	0	0	0	100	60	40
CH-47D (Chinook)	100	0	0	0	100	60	40
CH-47D (Chinook)	100	0	0	0	100	60	40
CH-47D (Chinook)	100	0	0	0	100	60	40
CH-47D (Chinook)	100	0	0	0	100	60	40
CH-47D (Chinook)	100	0	0	0	100	60	40
CH-47D (Chinook)	100	0	0	0	100	60	40
CH-47D (Chinook)	100	0	0	0	100	60	40
CH-47D (Chinook)	100	0	0	0	100	60	40
CH-47D (Chinook)	100	0	0	0	100	60	40
CH-47D (Chinook)	100	0	0	0	100	60	40
CH-47D (Chinook)	100	0	0	0	100	60	40
KIOWA Warrior	58	0	0	0	58	45	13
KIOWA Warrior	58	0	0	0	58	45	13
KIOWA Warrior	58	0	0	0	58	45	13
KIOWA Warrior	70	0	0	0	70	45	25
KIOWA Warrior	70	0	0	0	70	45	25
KIOWA Warrior	68	0	0	0	68	49	19
KIOWA Warrior	68	0	0	0	68	49	19
KIOWA Warrior	68	0	0	0	68	49	19
KIOWA Warrior	68	0	0	0	68	49	19
KIOWA Warrior	68	0	0	0	68	49	19
KIOWA Warrior	68	0	0	0	68	49	19
KIOWA Warrior	68	0	0	0	68	49	19
KIOWA Warrior	68	0	0	0	68	49	19

APPENDIX B: COST DATA TABLES

This appendix provides the summary cost data tables that are generated from cost information extracted directly from the program SARs. These tables are used to generate the cost figures in Chapters IV and V.

Table B1. Comparison of Adjusted and Unadjusted Cost Growth Data

Program Name	SAR Date	Est Type	Base Year	Initial Estimate Base-Year Dev Cost	Initial Estimate Base-Year Procurement Cost	Current Estimate Base-Year Dev Cost	Current Estimate Base-Year Procurement Cost	Base Year Schedule Cost Variance Dev Cost	Base Year Schedule Cost Variance Procurement Cost	Base Year Quantity Variance DEV	Base Year Quantity Variance PROC
C31											
AFATDS	1997	PdE	96	560	535.9	631.8	565	305	0	0	13.2
Adjusted	1995	DE	96	455.6	547.8	561.5	559	-4.3	0	0	138.7
AN/TTC-39	1984	DE	74	129	487.4	198.8	193.2	5.1	-82.8	0	-136.9
Adjusted	1984	DE	74	129	487.4	187.5	158.3	5.1	-82.8	0	-132.2
SCAMP	1994	DE	92	153.7	163.5	111.3	109	0	0	0	-20.7
Adjusted	1994	DE	92	153.7	163.5	111.3	109	0	0	0	-20.7
SMART-T	1997	DE	92	206.2	598.2	249	346.7	0	3	0	-34.6
Adjusted	1997	DE	92	206.2	598.2	249	346.7	0	3	0	-34.6
Longbow Apache	1997	PdE	96	1523.6	5866.1	1471.7	7061.3	0	0	0	0
Adjusted	1995	DE	96	1357.2	4818.8	1467.7	5871.9	0	-11.6	0	0
HELICOPTERS											
AH-64 (Apache)	1992	DE	72	609.4	1283	731.3	3142.1	94.6	46.2	0	541.6
Adjusted	1992	DE	72	609.4	1283	726.4	3458.7	80.1	68.8	0	744.7
RAH-66 (Comanche)	1997	PE	84	1756.2	TBD	5799	TBD	145.2	0	459.1	0
Adjusted	1997	PE	84	1756.2	TBD	5368.8	TBD	145.2	0	459.1	0
UH-60A (Blackhawk)	1981	DE	71	357.2	1584.4	366.4	2443.4	1.4	-106.8	-20.2	0
Adjusted	1981	DE	71	357.2	1584.4	360.2	2002.2	0.3	-105.8	-20.2	0
PGM											
ATACMS - BAT	1997	DE	91	488.5	1812.6	462.2	1523.6	17.1	17	0	0
Adjusted	1993	DE	91	702.1	1569.9	1367.7	1210.4	0	-0.3	0	-404.6
COPPERHEAD	1988	DE	75	109.3	783	134.6	571.4	-8.8	158.2	-1.7	-582.2
Adjusted	1998	DE	75	109.3	783	135.7	571.4	-7.7	138.5	0	-953.1
SADARM	1997	DE	89	237.7	248	356.2	1350.7	6.4	204.2	0	461.7
Adjusted	1997	DE	89	237.7	248	355.2	1350.7	6.4	204.2	0	461.7
TACTICAL MISSILE											
AAWS-M (Javelin)	1997	PdE	90	549.2	2849.6	736.1	2394	97.1	0	0	-1089.5
Adjusted	1996	DE	90	549.2	2849.6	736.1	2394	97.1	0	1	-1089.5
AGM-114 (Hellfire)	1993	DE	75	211.9	276.7	281	705.5	9.1	95.5	-2.7	165.4
Adjusted	1991	DE	75	211.9	276.7	283.4	717.4	9.1	100.5	.5	290.4
ATACMS/APAM BLI	1995	PdE	91	650.6	846.4	732.4	1577.5	0	40.9	0	364
Adjusted	1990	DE	91	757.8	563.4	650.6	846.4	0	-0.1	1	493
LANCE	1977	DE	70	417.8	220.2	450.5	477.3	22.1	35.6	-0.6	182.7
Adjusted	1977	DE	70	417.8	220.2	450.5	477.3	22.1	35.6	-0.6	182.7
Longbow Hellfire	1997	PdE	96	386.6	2249	455.3	1944.8	-1.1	0	0	-41.8
Adjusted	1995	DE	96	346.3	1534.7	462.1	1930.6	0	0	0	323.5
VEHICLES											
Crusader	1997	PE	95	2357	TBD	2669.8	0	156.2	0	0	118.6
Adjusted	1997	PE	95	2357	TBD	2669.8	0	156.2	0	0	118.6
M1 Abrams	1991	DE	72	1128	5604.5	2117.3	20935.1	0	103.3	0	8845.6
Adjusted	1985	DE	72	422.6	1970.2	575	5542.6	0	194.6	0	1830.4
Bradley	1992	DE	72	98.3	227.3	374.8	2944.2	13.8	79.8	0	902.3
Adjusted	1992	DE	72	98.3	376.3	259.6	1462.2	0	78.5	-11.1	-321.7
PLS (FHTV)	1996	PdE	93	39.5	1655.8	46.9	1130.7	0	0	0	-360.4
Adjusted	1992	DE	93	44.1	1922.9	44.9	1034.1	0	-0.2	0	-898.6

Table B2. Comparison of Adjusted and Unadjusted Cost Growth Data (Modifications)

Program Name	SAR Date	Est Type	Base Year	Initial Estimate Base-Year Dev Cost	Initial Estimate Base-Year Procurement Cost	Current Estimate Base-Year Dev Cost	Current Estimate Base-Year Procurement Cost	Base Year Schedule Cost Variance Dev Cost	Base Year Schedule Cost Variance Procurement Cost	Base Year Quantity Variance DEV	Base Year Quantity Variance PROC
VEHICLES											
BFVS/A3 Upgrade	1997	DE	94	394.1	2703.2	462.4	3884	0	131.7	-3	3
Adjusted	1997	DE	94	394.1	2703.2	462.4	3884	0	131.7	-3	3
M1A1					COST NOT BROKEN OUT						
M1A2											
M1 Abrams Upgrade	1997	PdE	95	755.4	6028.3	849.8	6166.5	0	0	0	377.7
Adjusted	1994	DE	95	656.1	4351.5	780.9	5773.5	0	61.4	0	0
PGM											
ATACMS - BAT P3I											
ATACMS - BAT BL II					COST NOT BROKEN OUT						
ATACMS - BAT IIA											
C3I											
ASAS					COST NOT BROKEN OUT						
MCS BL III											
TACTICAL MISSILE					COST NOT BROKEN OUT						
AGM-114 (Hellfire)											
STINGER - RMP	1994	PdE	83	52.3	2215.3	46.1	1138.2	0	84.6	0	-666.8
Adjusted											
ATACMS/APAM BLIA					COST NOT BROKEN OUT						
HELICOPTER											
CH-47D (Chinook)	1992	DE	75	76.1	806.4	86.3	1317	0	41.4	0	235.6
Adjusted	1992	DE	75	76.1	806.4	86.3	1317	0	41.4	0	235.6
KIOWA Warrior	1995	DE	82	213.5	1454.4	241.6	1960.5	0	106.2	0	-397.7
Adjusted	1995	DE	82	213.5	1454.4	241.6	1960.5	0	106.2	0	-36.1

Table B3. Adjusted Cost Growth Data

Program Name	SAR Date	Est Type	Base Year	Initial Estimate Base-Year Dev Cost	Initial Estimate Base-Year Procurement Cost	Current Estimate Base-Year Dev Cost	Current Estimate Base-Year Procurement Cost	Base Year Schedule Cost Variance Dev Cost	Base Year Schedule Cost Variance Procurement Cost	Base Year Quantity Variance DEV	Base Year Quantity Variance PROC
C31											
AFATDS Adjusted	1995	DE	96	455.6	547.8	561.5	559	-4.3	0	0	138.7
AN/TTC-39 Adjusted	1984	DE	74	129	487.4	187.5	158.3	5.1	-82.8	0	-132.2
SCAMP Adjusted	1994	DE	92	153.7	163.5	111.3	109	0	0	0	-20.7
SMART-T Adjusted	1997	DE	92	206.2	598.2	249	346.7	0	3	0	-34.6
LB APAHCHE Adjusted	1995	DE	96	1357.2	4818.8	1467.7	5871.9	0	-11.6	0	0
HELICOPTERS											
AH-64A Adjusted	1992	DE	72	609.4	1283	726.4	3458.7	80.1	68.8	0	744.7
RAH-66 Adjusted	1997	PE	84	1756.2	0	5368.8	0	145.2	0	459.1	0
UH-60A Adjusted	1981	DE	71	357.2	1584.4	360.2	2002.2	0.3	-105.8	-20.2	0
PGM											
ATACMS-BAT Adjusted	1993	DE	91	702.1	1569.9	1367.7	1210.4	0	-0.3	0	-404.6
COPPERHEAD Adjusted	1988	DE	75	109.3	783	135.7	571.4	-7.7	138.5	0	-953.1
SADARM Adjusted	1997	DE	89	237.7	248	355.2	1350.7	6.4	204.2	0	461.7
TACTICAL MISSILE											
JAVELIN Adjusted	1996	DE	90	549.2	2849.6	736.1	2394	97.1	0	1	-1089.5
AGM-114 HF Adjusted	1991	DE	75	211.9	276.7	283.4	717.4	9.1	100.5	.5	290.4
ATAMS/APAM Adjusted	1990	DE	91	757.8	563.4	650.6	846.4	0	-0.1	1	493
LANCE Adjusted	1977	DE	70	417.8	220.2	450.5	477.3	22.1	35.6	-0.6	182.7
LONGBOW HF Adjusted	1995	DE	96	346.3	1534.7	462.1	1930.6	0	0	0	323.5
VEHICLES											
CRUSADER Adjusted	1997	PE	95	2357	0	2669.8	0	156.2	0	0	118.6
M1 ABRAHMS Adjusted	1985	DE	72	422.6	1970.2	575	5542.6	0	194.6	0	1830.4
BRADLEY Adjusted	1992	DE	72	98.3	376.3	259.6	1462.2	0	78.5	-11.1	-321.7
PLS (FHTV) Adjusted	1992	DE	93	44.1	1922.9	44.9	1034.1	0	-0.2	0	-898.6
MODIFICATIONS											
Program Name	SAR Date	Est Type	Base Year	Initial Estimate Base-Year Dev Cost	Initial Estimate Base-Year Procurement Cost	Current Estimate Base-Year Dev Cost	Current Estimate Base-Year Procurement Cost	Base Year Schedule Cost Variance Dev Cost	Base Year Schedule Cost Variance Procurement Cost	Base Year Quantity Variance DEV	Base Year Quantity Variance PROC
VEHICLES											
BFVS/A3 UG Adjusted	1997	DE	94	394.1	2703.2	462.4	3884	0	131.7	-3	3
M1A1					COST NOT BROKEN OUT						
M1A2											
M1 ABRAMS UG Adjusted	1994	DE	95	656.1	4351.5	780.9	5773.5	0	61.4	0	0
PGM											
ATACMS - BAT P3I											
ATACMS - BAT BL II					COST NOT BROKEN OUT						
ATACMS - BAT IIA											
C3I											
ASAS					COST NOT BROKEN OUT						
MCS BL III											
TACTICAL MISSILE											
AGM-114 (Hellfire)					COST NOT BROKEN OUT						
STINGER - RMP Adjusted	1994	PdE	83	52.3	2215.3	46.1	1138.2	0	84.6	0	-666.8
ATACMS/APAM BLIA					COST NOT BROKEN OUT						
HELICOPTER											
CH-47D Adjusted	1992	DE	75	76.1	806.4	86.3	1317	0	41.4	0	235.6
KIOWA Adjusted	1995	DE	82	213.5	1454.4	241.6	1960.5	0	106.2	0	-36.1

Table B4. Cost Growth Factors

Program Name	SAR Date	Est Type	Base Year	Initail Total Est	Initial RDTE Est	Initial PROC Est	TCGF	TCGFA	STCFG	DCGF	DCGFA	SDCGF	PCGF	PCGFA	SPCGF	% SCH % Total Change
C31																
AFATDS	1995	DE	96	1003.4	455.6	547.8	1.117	0.978	0.996	1.232	1.232	0.991	1.020	0.767	1.000	19.91%
AN/TTC-39	1984	DE	74	616.4	129	487.4	0.561	0.775	0.874	1.453	1.453	1.040	0.325	0.596	0.830	56.14%
SCAMP	1994	DE	92	317.2	153.7	163.5	0.695	0.760	1.000	0.724	0.724	1.000	0.667	0.793	1.000	0.00%
SMART-T	1997	DE	92	804.4	206.2	598.2	0.741	0.784	1.004	1.208	1.208	1.000	0.580	0.637	1.005	-1.72%
Longbow Apache	1995	DE	96	6176	1357.2	4818.8	1.188	1.188	0.998	1.081	1.081	1.000	1.219	1.219	0.998	-1.00%
TOTAL				8917.4	2301.7	6615.7	4.301	4.486	4.872	5.699	5.699	5.030	3.810	4.012	4.833	73.33%
AVERAGE				1783.48	460.34	1323.14	0.860	0.897	0.974	1.140	1.140	1.006	0.762	0.802	0.967	14.67%
HELICOPTERS																
AH-64 (Apache)	1992	DE	72	1892.4	609.4	1283	2.212	1.818	1.079	1.192	1.192	1.131	2.696	2.115	1.054	9.62%
RAH-66 (Comanche)	1997	PE	84	1756.2	1756.2	0	3.057	2.796	1.083	3.057	2.796	1.083	0.000	0.000	0.000	4.60%
UH-60A (Blackhawk)	1981	DE	71	1941.6	357.2	1584.4	1.217	1.227	0.946	1.008	1.065	1.001	1.264	1.264	0.933	-23.92%
TOTAL				5590.2	2722.8	2867.4	6.485	5.841	3.107	5.257	5.053	3.215	3.959	3.379	1.987	-9.70%
AVERAGE				1863.4	907.6	1433.7	2.162	1.947	1.036	1.752	1.684	1.072	1.980	1.690	0.993	-3.23%
PGM																
ATACMS - BAT	1997	DE	91	2272	702.1	1569.9	1.135	1.313	1.000	1.948	1.948	1.000	0.771	1.029	1.000	-0.04%
COPPERHEAD	1988	DE	75	892.3	109.3	783	0.792	1.861	1.147	1.242	1.242	0.930	0.730	1.947	1.177	17.03%
SADARM	1997	DE	89	485.7	237.7	248	3.512	2.562	1.434	1.494	1.494	1.027	5.446	3.585	1.823	27.77%
TOTAL				3650	1049.1	2600.9	5.439	5.735	3.580	4.684	4.684	2.956	6.947	6.560	4.000	44.76%
AVERAGE				1216.7	349.7	866.967	1.813	1.912	1.193	1.561	1.561	0.985	2.316	2.187	1.333	14.92%
TACTICAL MISSILE																
AAWS-M (Javelin)	1996	DE	90	3398.8	549.2	2849.6	0.921	1.241	1.029	1.340	1.338	1.177	0.840	1.222	1.000	11.84%
AGM-114 (Hellfire)	1991	DE	75	488.6	211.9	276.7	2.048	1.453	1.224	1.337	1.335	1.043	2.593	1.543	1.363	49.53%
ATACMS/APAM BU	1990	DE	91	1321.2	757.8	563.4	1.133	0.759	1.000	0.859	0.857	1.000	1.502	0.627	1.000	0.03%
LANCE	1977	DE	70	638	417.8	220.2	1.454	1.169	1.090	1.078	1.080	1.053	2.168	1.338	1.162	53.57%
Longbow Hellfire	1995	DE	96	1881	346.3	1534.7	1.272	1.100	1.000	1.334	1.334	1.000	1.258	1.047	1.000	0.00%
TOTAL				7727.6	2283	5444.6	6.829	5.722	5.343	5.949	5.945	5.273	8.361	5.778	5.525	114.98%
AVERAGE				1545.5	456.6	1088.92	1.366	1.144	1.069	1.190	1.189	1.055	1.672	1.156	1.105	23.00%
VEHICLES																
Crusader	1997	PE	95	2357	2357	0	1.133	1.082	1.066	1.133	1.133	1.066	0.000	0.000	0.000	80.43%
M1 Abrams	1991	DE	72	2392.8	422.6	1970.2	2.557	1.792	1.081	1.361	1.361	1.000	2.813	1.884	1.099	10.27%
MICV (Bradley)	1992	DE	72	474.6	98.3	376.3	3.628	4.329	1.165	2.641	2.754	1.000	3.886	4.741	1.209	4.97%
PLS (FHTV)	1992	DE	93	1967	44.1	1922.9	0.549	1.005	1.000	1.018	1.018	1.000	0.538	1.005	1.000	-1.89%
TOTAL				7191.4	2922	4269.4	7.866	8.209	4.313	6.152	6.265	4.066	7.237	7.630	3.307	93.79%
AVERAGE				1797.9	730.5	1423.13	1.966	2.052	1.078	1.538	1.566	1.017	2.412	2.543	1.102	23.45%

Table B5. Cost Growth Factors (Modifications)

MODIFICATIONS														
Program Name	SAR Date	Est Type	Base Year	Initail Total Est	Initial RDTE Est	Initial PROC Est	TCGF	TCGFA	STCFG	DCGF	DCGFA	SDCGF	PCGF	PCGFA
VEHICLES														
BFVS/A3 Upgrade	1997	DE	94	3097.3	394.1	2703.2	1.40	1.40	1.04	1.17	1.18	1.00	1.44	1.44
MIA1									COST NOT BROKEN OUT					
M1A2														
M1 Abrams Upgrade	1994	DE	95	5007.6	656.1	4351.5	1.31	1.31	1.01	1.19	1.19	1.00	1.33	1.33
TOTAL				8104.9	1050.2	7054.7	2.712	2.712	2.055	2.364	2.371	2.000	2.764	2.762
AVERAGE				4052.5	525.1	3527.35	1.356	1.356	1.027	1.182	1.186	1.000	1.382	1.381
PGM														
ATACMS - BAT BL II									COST NOT BROKEN OUT					
ATACMS - BAT IIA														
C3I														
ASAS									COST NOT BROKEN OUT					
MCS BL III														
TACTICAL MISSILE														
AGM-114 (Hellfire)									COST NOT BROKEN OUT					
STINGER - RMP	1994	PdE	83						PdE ESTIMATE ONLY					
ATACMS/APAM BLIA									COST NOT BROKEN OUT					
HELICOPTER														
CH-47D (Chinook)	1992	DE	75	882.5	76.1	806.4	1.59	1.32	1.05	1.13	1.13	1.00	1.63	1.34
KIOWA Warrior	1995	DE	82	1667.9	213.5	1454.4	1.32	1.34	1.06	1.13	1.13	1.00	1.35	1.37
TOTAL				2550.4	289.6	2260.8	2.910	2.665	2.111	2.266	2.266	2.000	2.981	2.714
AVERAGE				1275.2	144.8	1130.4	1.455	1.333	1.055	1.133	1.133	1.000	1.491	1.357

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APPENDIX C: ADDITIONAL CYCLE TIME AND COST GRAPHS

This appendix provides additional graphs that provide more detail for the analysis presented in Chapters IV and V.

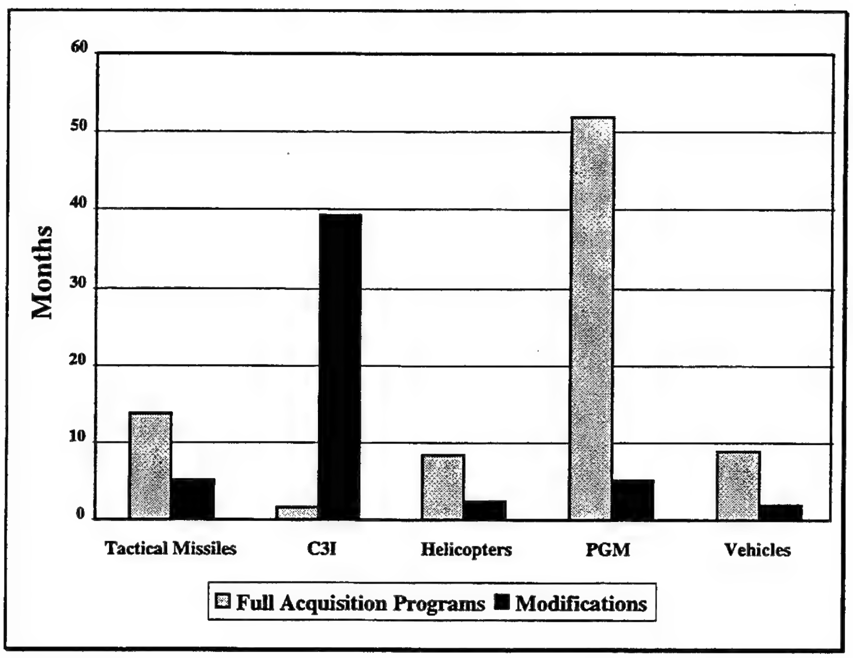

Figure C1. Average Growth (MS II – MS III)

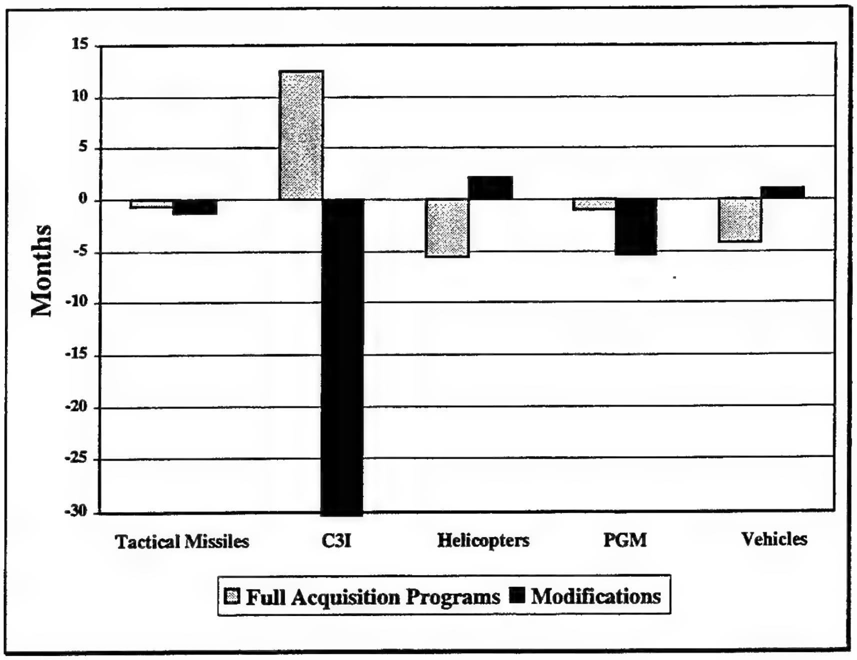

Figure C2. Average Growth (MS III – IOC)

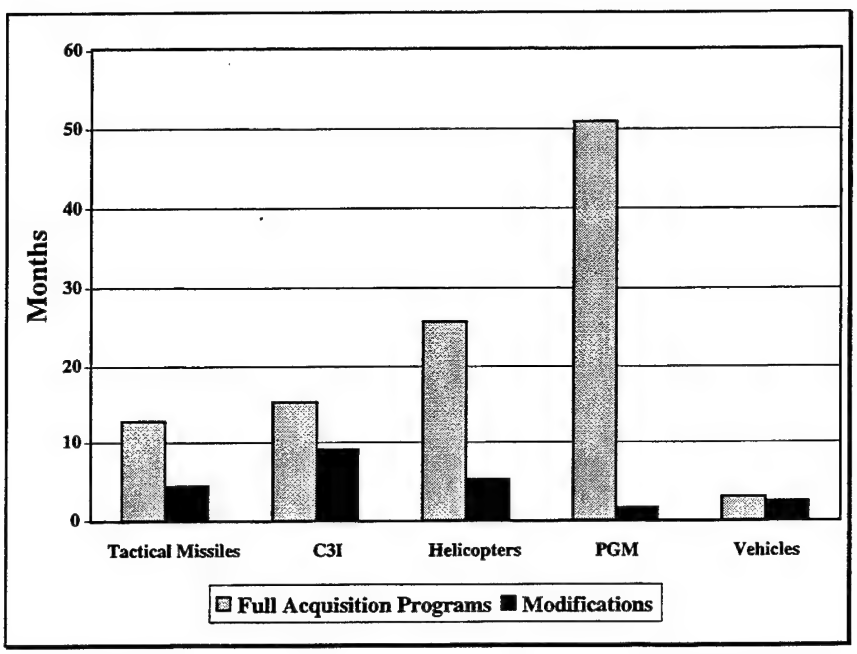

Figure C3. Average Growth (Program Start to IOC)

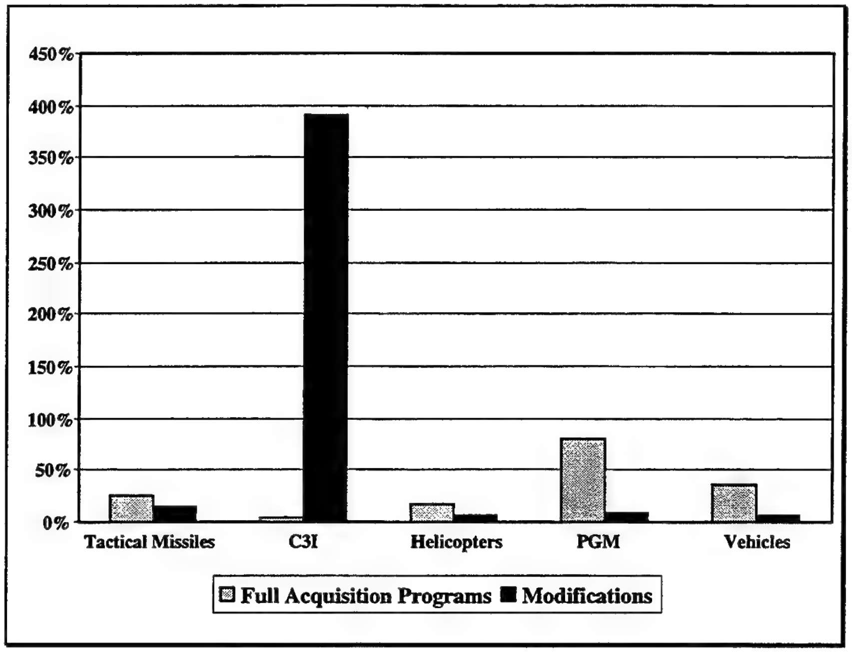

Figure C4. Average Percentage Growth (MS II – MS III)

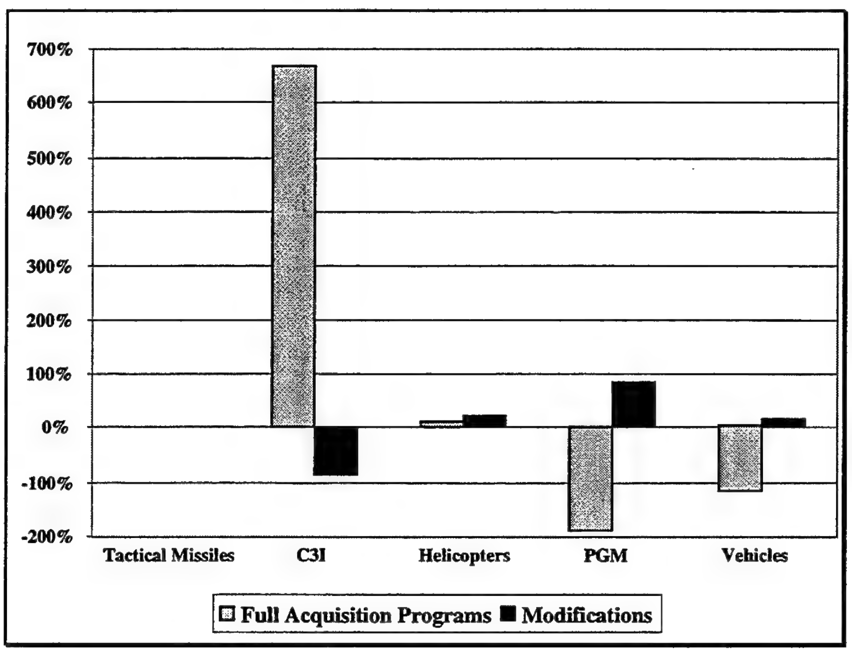

Figure C5. Average Percentage Growth (MS III – IOC)

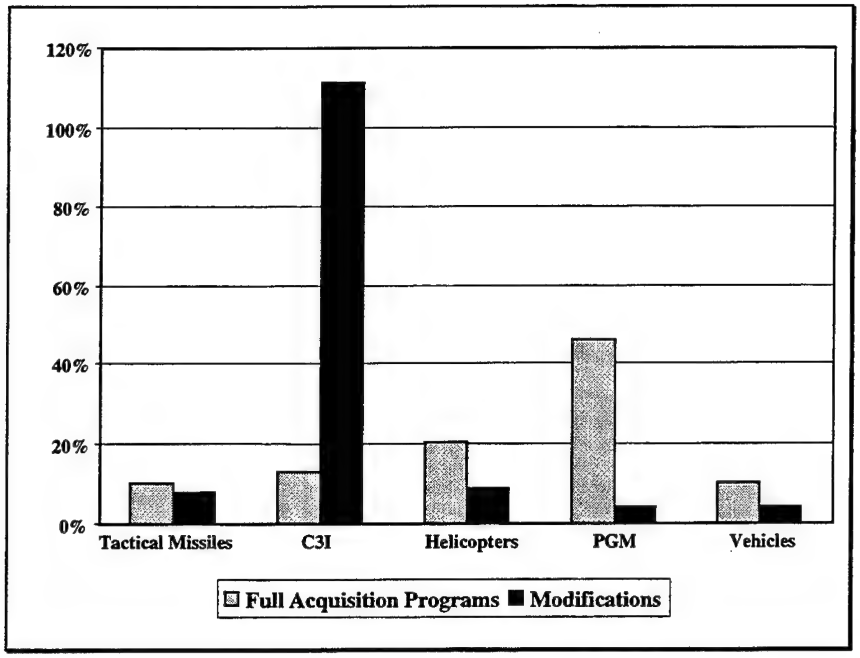

Figure C6. Average Percent Growth (Program Start to IOC)

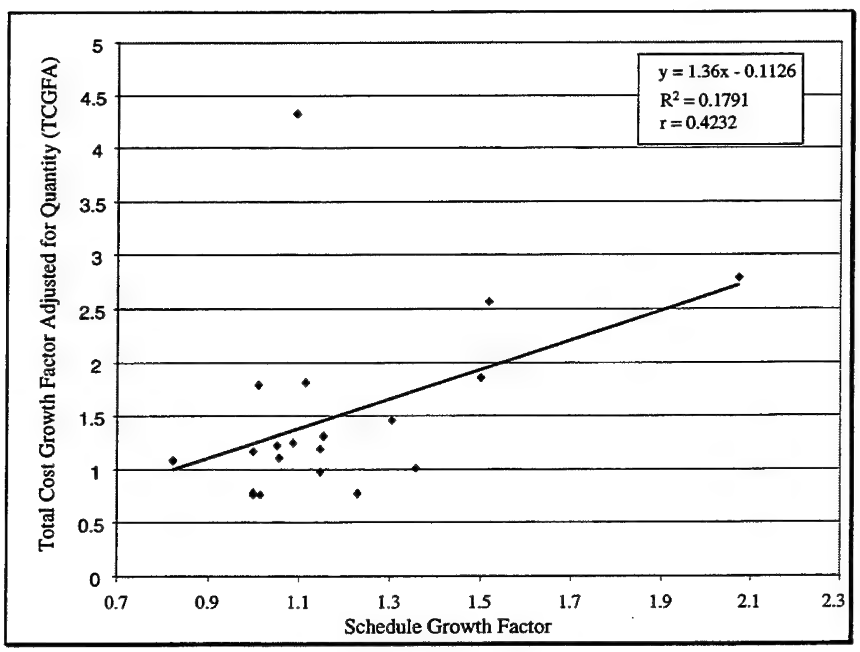

Figure C7. Correlation of TCGFA to Schedule Growth Factor

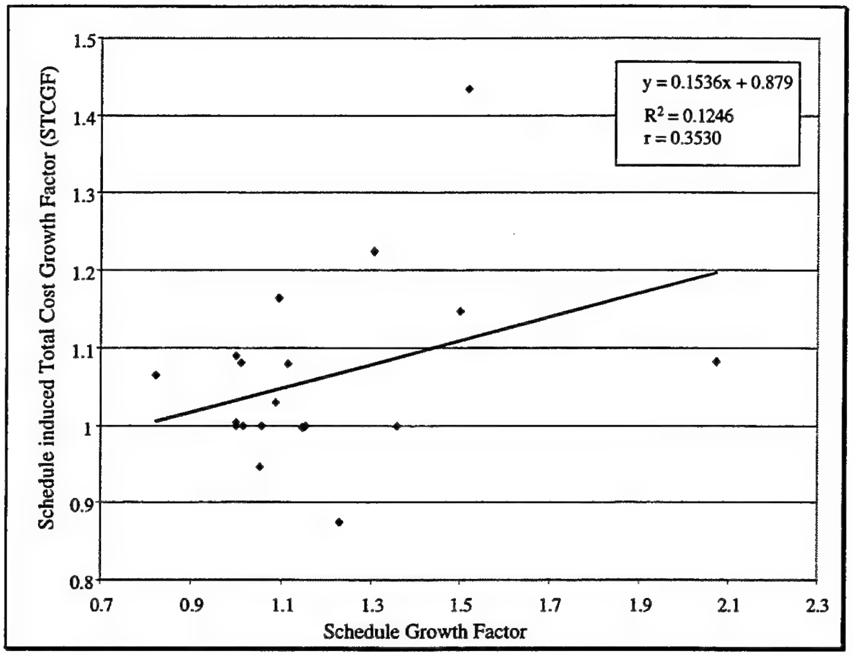

Figure C8. Correlation of STCGF to Schedule Growth Factor

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APPENDIX D: EXPLANATION OF PROGRAM COST ADJUSTMENTS

This appendix describes the cost adjustments that are made to programs in this research. This information permits future researchers to duplicate the numbers presented in this document or to adjust these numbers based on different assumptions and research objectives. In the correlation analysis, it is important to mention that the schedule growth factors are adjusted as necessary to correspond to the adjustments made to the cost data. If an earlier program SAR is used as the cost baseline due to cost adjustments, then the schedule growth factor is adjusted to that SAR year. This means that only schedule growth from program start to the adjusted cost baseline SAR year is used in the correlation analysis.

The first step is ensuring that the cost data in the final year SAR is correct. The DoD 7000.3-G SAR guidance states that the Previous Changes plus the Current Changes in the SAR cost variance section should equal the Previous Changes in the next year SAR. In other words, the Total Changes amount in the SAR cost variance section should equal the subtotal in the Previous Changes section of the next year's SAR. "Corrections to Previous Changes will be shown as Current Changes. For example, if the previous Other Changes of +15 should have been classified as Estimating, the Current Changes would show -15 for Other and +15 for Estimating (DoD 7000.3-G, p.3-1)."

In some cases, the Total Changes amount in a SAR did not equate to the sum of the Previous Change amounts and the Current Change amounts. In some of the program SARs, the Total Changes from the previous year SAR do not equal the Previous Change subtotal in the next year's SAR. Some of the variance categories seem to be adjusted arbitrarily. In

these cases, the change explanations are analyzed either to allow the adjustment if there is an explanation or to adjust the cost variance if there is no reasonable explanation. These adjustments are presented in table format for each program that is adjusted. The table format includes the SAR year and cost information for the program SAR that is used as the initial current estimate, which is presented in italics type. Each table then shows the necessary adjustments, by SAR year, that are made to each program. These adjustments are shown as they appear in the program SAR.

As an example, use the information in Table D1. In this case, there is an unexplained addition of +430.2 in the DEV Previous Cost from 1987 to 1988. This amount is entered in the table and then subtracted from the Current DEV Estimate to determine the adjusted cost. If the change had been an unexplained subtraction of a cost then this negative amount is entered into the table and again subtracted from the Current Estimate, which results in adding this subtracted cost to the Current Estimate. The last entry in each table is the adjusted cost information that is utilized for the calculations of the cost growth factors, which is presented in bold type. The last cost data line in each table corresponds to the cost data lines in the cost data tables in Appendix B.

Helicopters

Comanche Program

An example of a reasonable explanation occurs in the RAH-66 Comanche program. There is a discrepancy between the 1989 and 1990 SARs in the schedule variance category. The Previous Changes section of the 1990 SAR includes +145 in the schedule variance that did not appear in either of the1989 SAR's Previous Changes or Current Changes sections. The variance explanation shows that the +145 is added to the schedule variance due to DoD

direction to rebaseline the program. Although this amount should have been incorporated in the current variance change section, the explanation makes sense and the cost is not adjusted.

Table D1. RAH-66 Cost Adjustment Data

SAR Year	Initial DEV Cost	Initial PROC Cost	Current DEV Cost	Current PROC Cost	Sched DEV Var Cost	Sched PROC Var Cost	QTY DEV Var Cost	QTY PROC Var Cost
1997	*1756.2*	*0*	*5799*	*0*	*145.2*	*0*	*459.1*	*0*
Changes								
87-88			430.2					
Adj Cost	**1756.2**	**0**	**5368.8**	**0**	**145.2**	**0**	**459.1**	**0**

AH-64A Program

Table D2. AH-66A Cost Adjustment Data

SAR Year	Initial DEV Cost	Initial PROC Cost	Current DEV Cost	Current PROC Cost	Sched DEV Var Cost	Sched PROC Var Cost	QTY DEV Var Cost	QTY PROC Var Cost
1992	*609.4*	*1283*	*731.3*	*3142.1*	*94.6*	*46.2*	*0*	*541.6*
Changes								
78-79			37.3	192.7	14.5	69.5		
79-80			-.8	-11.4				
80-81			.9	-15.6		-96.9		
83-84				-5.3		4.8		-2.1
88-89			-32.5	-477				-201
Adj Cost	**609.4**	**1283**	**726.4**	**3458.7**	**80.1**	**68.8**	**0**	**744.7**

UH-60A Program

Table D3. UH-60A Cost Adjustment Data

SAR Year	Initial DEV Cost	Initial PROC Cost	Current DEV Cost	Current PROC Cost	Sched DEV Var Cost	Sched PROC Var Cost	QTY DEV Var Cost	QTY PROC Var Cost
1981	*357.2*	*1584.4*	*366.4*	*2443.4*	*1.4*	*-106.8*	*-20.2*	*0*
Changes								
78-79			4.7	5.2	1.1			
79-80			1.4	-2.2		1.9		
80-81			.1	438.2		-2.9		
Adj Cost	**357.2**	**1584.4**	**360.2**	**2002.2**	**.3**	**105.6**	**-20.2**	**0**

OH-58D Program

Table D4. OH-58D Cost Adjustment Data

SAR Year	Initial DEV Cost	Initial PROC Cost	Current DEV Cost	Current PROC Cost	Sched DEV Var Cost	Sched PROC Var Cost	QTY DEV Var Cost	QTY PROC Var Cost
1995	*213.5*	*1454.4*	*241.6*	*1960.5*	*0*	*106.2*	*0*	*-397.7*
Changes								
88-89								-361.6
Adj Cost	**213.5**	**1454.4**	**241.6**	**1960.5**	**0**	**106.2**	**0**	**-36.1**

There is also an unexplained change in the total amount between 1988 and 1989; however, this amount is not adjusted. The amount is not adjusted because there is not a program SAR for 1990. Therefore, it is impossible to determine what happened between 1989 and 1991. The quantity variances are correct between 1989 and 1991.

Vehicles

M1 Abrams

The M1 Abrams program's last SAR is 1991; however, the cost information for this program is extracted from the 1985 SAR. The 1985 SAR cost data is used because after

1985 the M1 modifications, M1A1 and M1A2, are combined into the M1 SAR. The schedule and performance data is separated in the SAR but the cost information is combined. There is no way to separate the cost data based on the program SARs.

Table D5. M1 Abrams Cost Adjustment Data

SAR Year	Initial DEV Cost	Initial PROC Cost	Current DEV Cost	Current PROC Cost	Sched DEV Var Cost	Sched PROC Var Cost	QTY DEV Var Cost	QTY PROC Var Cost
1985	*422.6*	*1970.2*	*630.8*	*5512.9*	*0*	*123.1*	*0*	*1830.4*
Changes								
79-80			1	-6.6				
80-81			61.8			-14.1		
81-82			-1.6	-12.9				
82-83			-5.4	-10.2		-57.4		
Adj Cost	**422.6**	**1970.2**	**575**	**5542.6**	**0**	**194.6**	**0**	**1830.4**

There is also a difference of -778.5 in the PROC cost from 1980 - 1981. This cost is unclear so calculations with and without this cost are compared to IDA cost growth factors for the M1. The calculated cost growth factor, not adjusting for the -778.5, is the closest to the IDA numbers so this adjustment is not made.

Bradley Program

This program is adjusted to reflect when the actual Bradley program started. From 1973 to 1977, this program is the XM-23, Mechanized Infantry Fighting Vehicle. In 1978, the program incorporates two systems; the XM2, Infantry Fighting Vehicle and the XM 3, Cavalry Fighting Vehicle. In 1979, the program actually became the Bradley. The Bradley program cost is adjusted to only incorporate cost associated with the Bradley. This is accomplished by subtracting the cost amounts in the Previous Change Section of the 1979 SAR from the final year SAR's Current Estimate.

Table D6. Bradley Cost Adjustment Data

SAR Year	Initial DEV Cost	Initial PROC Cost	Current DEV Cost	Current PROC Cost	Sched DEV Var Cost	Sched PROC Var Cost	QTY DEV Var Cost	QTY PROC Var Cost
1992	*98.3*	*227.3*	*374.8*	*2944.2*	*13.8*	*79.8*	*0*	*902.3*
Changes								
Prior 1979			120.6	1484.3	13.8	1.3	11.1	1224
82-83			-5.4	-2.3				
Adj Cost	**98.3**	**376.3**	**259.6**	**1462.2**	**0**	**78.5**	**-11.1**	**-321.7**

The Initial PROC cost is adjusted to reflect the initial baseline. The baseline changed from 376.3 to 227.3 during the life of the program.

The rest of the vehicle programs did not have any adjustments of the type shown above. The only adjustments to these programs are which final SAR year is used. The PLS program's 1992 SAR is used because years 1993 - 1996 incorporate PdEs. This also holds true for the M1A2 Upgrade in which the 1994 SAR is used because the 1995 - 1997 SARs are PdEs. The last SAR is used for both the Crusader and the BFVS Upgrade.

Tactical Missiles

AGM-114 Hellfire

The following adjustments are made to the Hellfire program.

Table D7. Hellfire Cost Adjustment Data

SAR Year	Initial DEV Cost	Initial PROC Cost	Current DEV Cost	Current PROC Cost	Sched DEV Var Cost	Sched PROC Var Cost	QTY DEV Var Cost	QTY PROC Var Cost
1991	*211.9*	*276.7*	*287.8*	*723.1*	*9.1*	*94.6*	*2.7*	*173.1*
Changes								
78-79			1	44.8			2.2	
79-80				8.4				
80-81				-15.2		-18.2		
82-83			3.4	-39.1				
83-84				6.8		12.3		-117.3
Adj Cost	**211.9**	**276.7**	**283.4**	**717.4**	**9.1**	**100.5**	**.5**	**290.4**

The 1991 SAR is used for this program because the Hellfire II's cost is included in SAR years 1992 and 1993.

The rest of the programs in this commodity need no adjustments as shown for the AGM 114. For the Javelin program, the 1996 SAR is used because the 1997 SAR is a PdE. The 1990 SAR is used for the ATACMS/APAM for the same reason, the 1991 - 1995 SARs are PdEs. The Longbow Hellfire program's 1995 SAR is used because the years 1996 - 1997 are PdEs. The Lance's last SAR year is used for the cost growth calculations.

C3I

AN/TTC-39

The following adjustments are made to the AN/TTC-39 program.

Table D8. AN/TTC-39 Cost Adjustment Data

SAR Year	Initial DEV Cost	Initial PROC Cost	Current DEV Cost	Current PROC Cost	Sched DEV Var Cost	Sched PROC Var Cost	QTY DEV Var Cost	QTY PROC Var Cost
1984	*129*	*487.4*	*198.8*	*193.2*	*5.1*	*-82.8*	*0*	*-136.9*
Changes								
79-80			10.3	21.1				-1.3
80-81			1	3				
81-82				4.1				
82-83				6.7				-3.4
Adj Cost	**129**	**487.4**	**187.5**	**158.3**	**5.1**	**-82.8**	**0**	**-132.2**

Longbow AH-64

The Longbow AH-64 program data does not include the 1996 and 1997 SARs because these SARs contain PdEs. This program data includes both the fire control system and the necessary airframe modification costs. This program is included in the C3I commodity because the DoD approved CTAT database classifies this program as avionics. Since this is the only program with an avionics classification, this program is included with the C3I commodity for this research based on its electronic nature.

The AFATDS program's 1995 SAR is used because the 1996 and 1997 SARs contain PdEs. The last year SARs for the SCAMP and the SMART-T programs are used in the cost growth factor calculations.

PGM

Copperhead

The following adjustments are made to the Copperhead program.

Table D9. Copperhead Cost Adjustment Data

SAR Year	Initial DEV Cost	Initial PROC Cost	Current DEV Cost	Current PROC Cost	Sched DEV Var Cost	Sched PROC Var Cost	QTY DEV Var Cost	QTY PROC Var Cost
1988	*109.3*	*783*	*134.6*	*571.4*	*-8.8*	*158.2*	*-1.7*	*-582.2*
Changes								
76-77					-.2			
77-78			-1.1		-.9	3.7	-1.7	
80-81						-3.5		
81-82						14.7		
82-83						4.8		370.9
Adj Cost	**109.3**	**783**	**135.7**	**571.4**	**-7.7**	**138.5**	**0**	**-953.1**

SADARM

The SADARM program is adjusted to only include the cost data from the SADARM 155mm projectile. Up to 1995 the program also included cost information for a MLRS SADARM rocket; however, this part of the program was cancelled in 1995.

Table D10. SADARM Cost Adjustment Data

SAR Year	Initial DEV Cost	Initial PROC Cost	Current DEV Cost	Current PROC Cost	Sched DEV Var Cost	Sched PROC Var Cost	QTY DEV Var Cost	QTY PROC Var Cost
1997	*237.7*	*248*	*356.2*	*1350.7*	*6.4*	*204.2*	*0*	*461.7*
Changes								
92-93			1					
Adj Cost	**237.7**	**248**	**355.2**	**1350.7**	**6.4**	**204.2**	**0**	**461.7**

The ATACMS/BAT program's 1993 SAR is used because the SARs from 1994 on include program upgrade combined cost information.

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APPENDIX E: MULTIPLE REGRESSION INFORMATION

This appendix provides the results of additional multiple regression analyses conducted on the cost growth factors. Table E1 presents the results of a natural log multiple regression. In this table, the dependent variables are the natural log cost growth factors. All of the independent variables are also in natural log form.

Table E1. Multiple Regression Analysis

Dependent Variable	LN Initial Cost Coefficient	LN Initial Cost P-Value	LN SGF Coefficient	LN SGF P-Value	LN Initial Schedule Coefficient	LN Initial Schedule P-Value
LN TCGF	0.1013	0.4387	1.311	0.0295	1.0374	0.02298
LN TCGFA	**0.1518**	**00624**	**1.411**	**0.0005**	**0.3048**	**0.2279**
LN STCGF	-0.0272	0.3523	0.2152	0.0965	0.0837	0.3733

Table E1A provides the "R^2" and "n" values for the dependent variables in Table E1.

Table E1A. Multiple Regression Analysis

Dependent Variables	**R^2**	**n**
LN TCGF	.4118	19
LN TCGFA	.6007	19
LN STCGF	.2219	19

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